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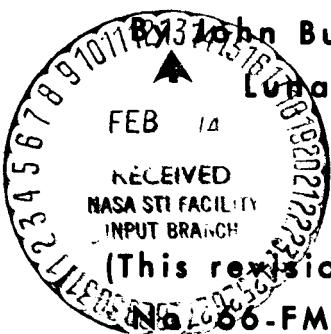
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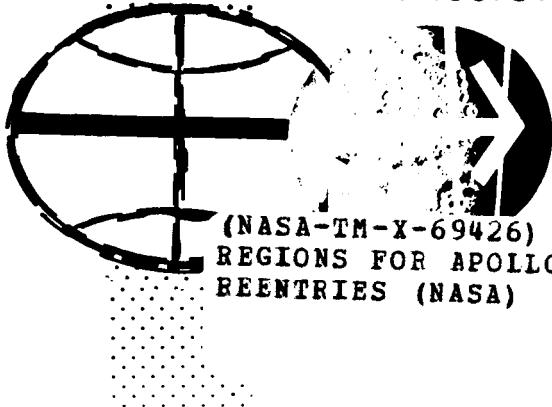
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COMMUNICATION BLACKOUT REGIONS  
FOR APOLLO LUNAR MISSION  
REENTRIES

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PROJECT APOLLO

COMMUNICATION BLACKOUT REGIONS  
FOR APOLLO LUNAR MISSION REENTRIES

By John Burton and Nicholas W. Kirincich  
Lunar Mission Analysis Branch

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April 18, 1968

MISSION PLANNING AND ANALYSIS DIVISION  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS

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## COMMUNICATION BLACKOUT REGIONS FOR APOLLO LUNAR MISSION REENTRIES

By John Burton and Nicholas W. Kirincich

### SUMMARY

This report is presented as a result of the lower lift-to-drag ratio (L/D) which is now expected for reentries for the Apollo lunar return missions and of a slight change to the reentry guidance logic.

It presents the updated velocity-versus-altitude plots which show the VHF-band, S-band, and C-band blackout regions. Plots of time versus altitude and range versus altitude for each case are provided to complement each velocity-versus-altitude plot.

These plots reveal that the steeper reentry flight-path angles and/or longer ranges to targets result in the possible acquisition of communication during the ship phase of the reentry. Also the steeper flight-path angles enter the blackout region earlier than the nominal case.

### INTRODUCTION

A preliminary study of the communications blackout region for the AS-504 reentry was published in reference 1. Since that time the nominal mission characteristics have been revised and the reentry guidance logic has been updated.

The current nominal lunar landing mission has a reentry inertial velocity of 36 066 fps and an inertial flight-path angle of  $-6.40^\circ$ . To assist in the establishment of preliminary reentry and recovery procedure, it is necessary to define communication blackout regions for nominal and non-nominal entry conditions. As in the preliminary study, the flight-path angle, range to target, and L/D are varied while the nominal entry velocity is held constant.

This data is presented to reveal the effect the guidance logic revisions have on the new nominal flight characteristics.

## ANALYSIS AND RESULTS

The trajectories presented were calculated using a modified version of the GE MASS program and the Colossus reentry guidance logic (ref. 2). The reentry flight-path angles were chosen to be in the middle, near the undershoot, and near the overshoot boundaries of the reentry corridor. The target ranges from an altitude of 400 000 ft were 1500, 2000, and 2500 n. mi.

Each case was run for L/D's of 0.25, 0.30, and 0.36 with the entry velocity of 36 066 fps.

Figures 1 through 27 present, for all L/D's, velocity versus altitude, altitude versus range, and altitude versus time from reentry in a recurring sequence for various combinations of target ranges and flight-path angles. The velocity-versus-altitude plots (fig. 1, 4, 7, ..., 25) show VHF-band, S-band, and C-band blackout regions. The altitude-versus-range and altitude-versus-time-from-reentry plots (the remaining plots) provide an easy trajectory reference for the velocity and altitude data.

Data used to define the VHF-band, S-band, and C-band communication blackout curves were obtained from reference 3. Using this data for the nominal lunar return inertial reentry velocity of 36 066 fps, communication blackout for the C-band, S-band, and VHF-band frequencies will occur at the altitude of 294 000 ft, 305 000 ft, and 332 000 ft, respectively. This is true for all the trajectories investigated; however, the elapsed time from 400 000 ft to communication blackout varied depending on the entry inertial flight-path angle, such that the steeper the flight-path angle, the earlier the blackout altitude was reached. Range to target had no effect on elapsed time to the initial blackout altitude since the guidance logic will fly the same trajectory to 0.05 g or about 300 000-ft altitude, at which point blackout altitudes have essentially been reached. There were no effects on elapsed time to blackout due to L/D changes since the aerodynamic forces are essentially negligible above an altitude of 300 000 ft. Table I shows the communication blackout altitudes and elapsed time from 400 000 ft to blackout for the cases investigated.

After entry into the communication blackout region the spacecraft might be required to gain altitude in order to reach a long target. Because of this gain in altitude or so called "skip phase", the spacecraft is able to exit the blackout region. In a few cases the C-band and/or S-band frequency was reacquired early in the trajectory and was maintained for the rest of the flight; however, in most cases where there was a skipout of the communication blackout region the blackout region was reentered.

Table II presents the elapsed time and altitudes that each trajectory spent in and out of the blackout region. This table also shows which

trajectories do not gain enough altitude to leave the blackout region during the skip phase of the trajectory. It also shows those trajectories that leave the blackout regions and do not slip in again.

#### CONCLUSION

The same two basic trends were observed in this study as the previous one. The first is that for a steep reentry flight-path angle, the guidance logic will steer to a higher peak altitude than it will for the nominal reentry flight-path angle. The guidance logic will also steer the spacecraft to a higher peak altitude for the longer ranges to target. Thus, for a steep reentry flight-path angle and/or long range to target a higher peak altitude will be reached which could result in communication acquisition during the skip phase of the reentry.

A second trend is that for a steeper reentry flight-path angle the blackout region will be entered earlier than for the nominal reentry flight-path angle.

TABLE I.- INITIAL BLACKOUT TIMES AND ALTITUDES

Entry flight-path angle, deg	C-band blackout		S-band blackout		VHF blackout	
	Time from 400 000 ft, sec	Altitude, ft	Time from 400 000 ft, sec	Altitude, ft	Time from 400 000 ft, sec	Altitude, ft
-5.7	36	294 000	32	305 000	20	332 000
-6.3	32	294 000	28	305 000	20	332 000
-6.7	30	294 000	26	305 000	18	332 000

TABLE II.- ACQUISITION TIMES, LOSS TIMES AND ALTITUDES OF COMMUNICATIONS  
(a) VHF

Entry flight-path angle, deg	Range, n. mi.	Lift/drag, nd	Acquisition		Second loss	Time from 400 000 ft, min:sec	Final acquisition
			Time from 400 000 ft, min:sec	Altitude, ft			
a -5.7	1500	.25	6:18	140 000	--	--	--
a -5.7	1500	.30	6:16	135 000	--	--	--
a -5.7	1500	.36	6:50	120 000	--	--	--
a -6.3	1500	.25	6:44	130 000	--	--	--
a -6.3	1500	.30	6:30	130 000	--	--	--
a -6.3	1500	.36	6:30	135 000	--	--	--
a -6.7	1500	.25	6:43	125 000	--	--	--
a -6.7	1500	.30	6:46	122 000	--	--	--
a -6.7	1500	.36	6:44	120 000	--	--	--
a -5.7	2000	.25	8:36	132 000	--	--	--
a -5.7	2000	.30	8:42	120 000	--	--	--
a -5.7	2000	.36	8:33	120 000	--	--	--
a -6.3	2000	.25	8:43	125 000	--	--	--
a -6.3	2000	.30	8:50	125 000	--	--	--
a -6.3	2000	.36	9:50	120 000	--	--	--
-6.7	2000	.25	3:48	280 000	6:00	280 000	8:46
a -6.7	2000	.30	8:42	134 000	--	--	--
a -6.7	2000	.36	8:50	129 000	--	--	--
a -5.7	2500	.25	10:24	130 000	--	--	--
a -5.7	2500	.30	10:50	125 000	--	--	--
a -5.7	2500	.36	10:46	127 000	--	--	--
-6.3	2500	.25	4:50	285 000	6:30	283 000	9:22
a -6.3	2500	.30	10:52	128 000	--	--	--
a -6.3	2500	.36	11:00	120 000	--	--	--
-6.7	2500	.25	3:30	285 000	7:30	284 000	10:34
-6.7	2500	.30	4:16	287 000	6:40	285 000	10:50
-6.7	2500	.36	3:46	284 000	8:02	284 000	10:50

<sup>a</sup>The spacecraft does not leave the blackout region during the skip phase of this trajectory.

TABLE II.- ACQUISITION TIMES, LOSS TIMES AND ALTITUDES OF COMMUNICATIONS - Continued

Entry flight-path angle, deg	Range, n. mi.	Lift/drag, nd	(b) S-band			Final acquisition		
			Time from 400 000 ft, min:sec	Acquisition	Time from 400 000 ft, min:sec	Second loss	Altitude, ft	Time from 400 000 ft, min:sec
a -5.7	1500	.25	3:48	195 000	--	--	--	--
a -5.7	1500	.30	3:52	195 000	--	--	--	--
a -5.7	1500	.36	3:54	187 000	--	--	--	--
a -6.3	1500	.25	3:32	205 000	--	--	--	--
a -6.3	1500	.30	3:32	207 000	--	--	--	--
a -6.3	1500	.36	3:46	200 000	--	--	--	--
-6.7	1500	.25	2:50	217 000	5:36	195 000	6:38	135 000
-6.7	1500	.30	3:16	214 000	5:47	181 000	6:30	144 000
-6.7	1500	.36	3:40	210 000	5:56	174 000	6:24	137 000
-6.7	2000	.25	4:00	225 000	6:46	205 000	7:50	168 000
-5.7	2000	.30	4:10	225 000	6:52	205 000	8:24	135 000
-5.7	2000	.36	4:04	225 000	6:56	207 000	8:18	132 000
-6.3	2000	.25	3:16	230 000	6:54	215 000	8:19	140 000
-6.3	2000	.30	3:43	230 000	6:38	211 000	8:17	154 000
-6.3	2000	.36	3:58	225 000	6:58	200 000	8:16	155 000
-6.7	2000	.25	2:38	228 000	7:14	217 000	8:26	140 000
-6.7	2000	.30	2:50	228 000	7:02	215 000	8:28	140 000
-6.7	2000	.36	3:09	228 000	6:42	214 000	8:28	145 000
-6.7	2000	.36	3:50	237 000	8:24	226 000	10:18	140 000
-5.7	2500	.25	3:54	236 000	8:10	221 000	10:10	160 000
-5.7	2500	.30	4:00	235 000	8:03	223 000	10:19	146 000
-5.7	2500	.36	3:08	235 000	8:10	225 000	10:02	165 000
-6.3	2500	.25	3:24	235 000	8:12	227 000	10:18	155 000
-6.3	2500	.30	3:48	237 000	7:52	225 000	10:14	165 000
-6.3	2500	.36	3:48	229 000	8:30	226 000	10:00	155 000
-6.7	2500	.25	2:32	233 000	8:04	226 000	10:00	166 000
-6.7	2500	.30	2:52	230 000	8:58	226 000	9:52	140 000
-6.7	2500	.36	2:50					

a In this case the spacecraft leaves the blackout region during the skip phase and does not reenter the blackout region during the second-entry phase.

TABLE II.- ACQUISITION TIMES, LOSS TIMES AND ALTITUDES OF COMMUNICATIONS - Concluded

Entry flight-path angle, deg	Range, n. mi.	Lift/drag, nd	(c) C-band			Second loss	Altitude, ft	Final acquisition
			Time from 400 000 ft, min:sec	Acquisition	Time from 400 000 ft, min:sec			
a -5.7	1500	.25	3:28	190 000	—	—	—	—
a -5.7	1500	.30	3:50	195 000	—	—	—	—
a -5.7	1500	.36	3:24	176 000	—	—	—	—
a -6.3	1500	.25	3:00	192 000	—	—	—	—
a -6.3	1500	.30	3:00	192 000	—	—	—	—
a -6.3	1500	.36	3:14	190 000	—	—	—	—
a -6.7	1500	.25	2:24	199 000	—	—	—	—
a -6.7	1500	.30	2:44	200 000	—	—	—	—
a -6.7	1500	.36	2:52	198 000	—	—	—	—
a -6.7	2000	.25	3:20	212 000	—	—	—	—
a -5.7	2000	.30	3:20	210 000	—	—	—	—
a -5.7	2000	.36	3:20	209 000	—	—	—	—
a -6.3	2000	.25	2:49	212 000	—	—	—	—
a -6.3	2000	.30	2:54	214 000	—	—	—	—
a -6.3	2000	.36	3:11	211 000	—	—	—	—
-6.7	2000	.25	2:16	205 000	7:42	185 000	8:16	150 000
-6.7	2000	.30	2:28	209 000	7:37	180 000	8:04	155 000
a -6.7	2000	.36	2:42	210 000	—	—	—	—
a -6.7	2500	.25	3:16	220 000	—	—	—	—
a -5.7	2500	.30	3:20	220 000	—	—	—	—
a -5.7	2500	.36	3:20	219 000	—	—	—	—
a -6.3	2500	.25	2:44	215 000	—	—	—	—
a -6.3	2500	.30	2:50	217 000	—	—	—	—
a -6.3	2500	.36	3:06	220 000	—	—	—	—
-6.7	2500	.25	2:14	210 000	7:14	195 000	9:36	160 000
a -6.7	2500	.30	2:28	213 000	—	—	—	—
-6.7	2500	.36	2:32	211 000	7:46	195 000	10:16	150 000

<sup>a</sup>In this case the spacecraft leaves the blackout region during the skip phase and does not reenter the blackout region during the second-entry phase.

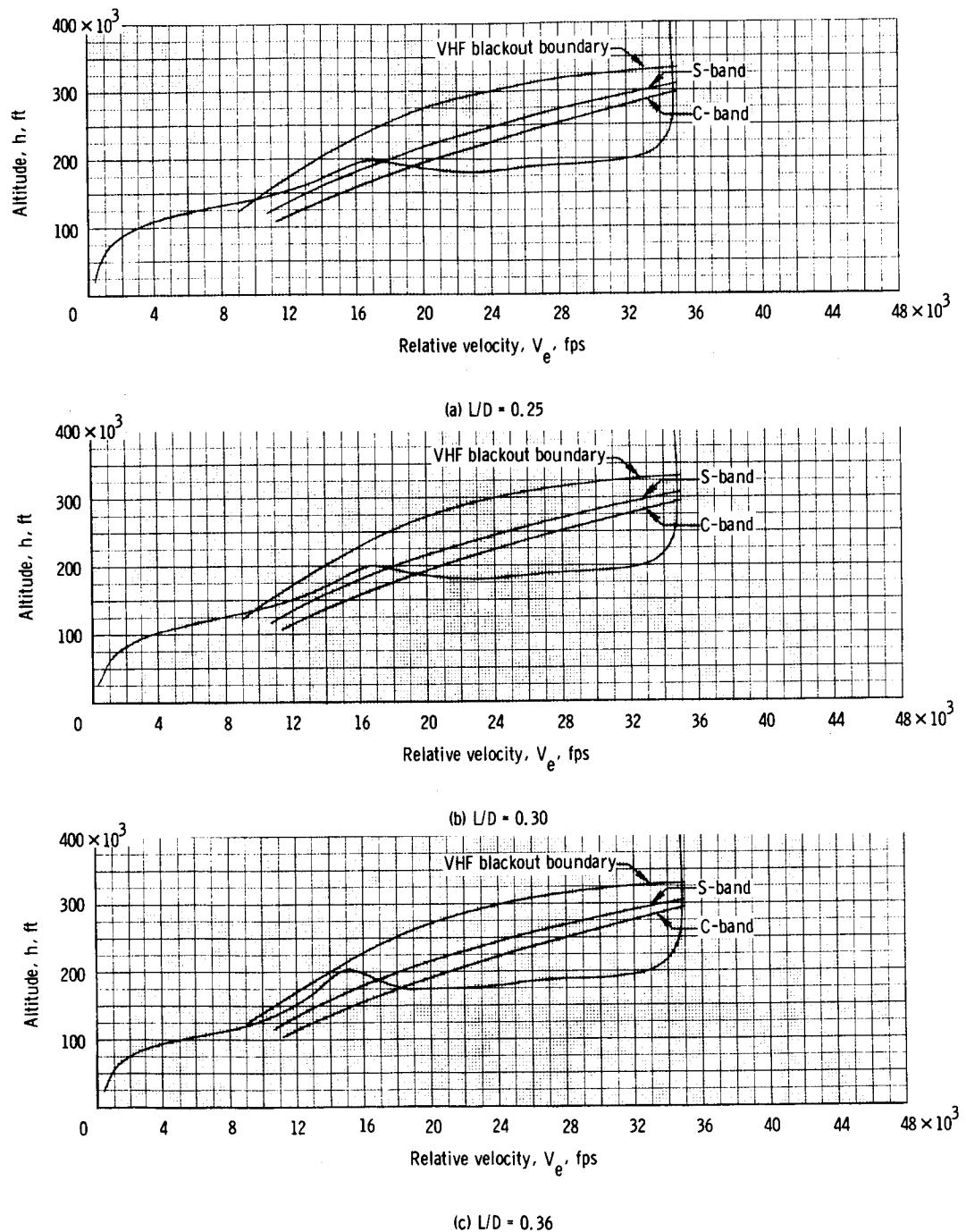


Figure 1. - Communications blackout region for lunar returns with a range to target at reentry of 1500 nautical miles and a flight-path angle of -5.7 degrees.

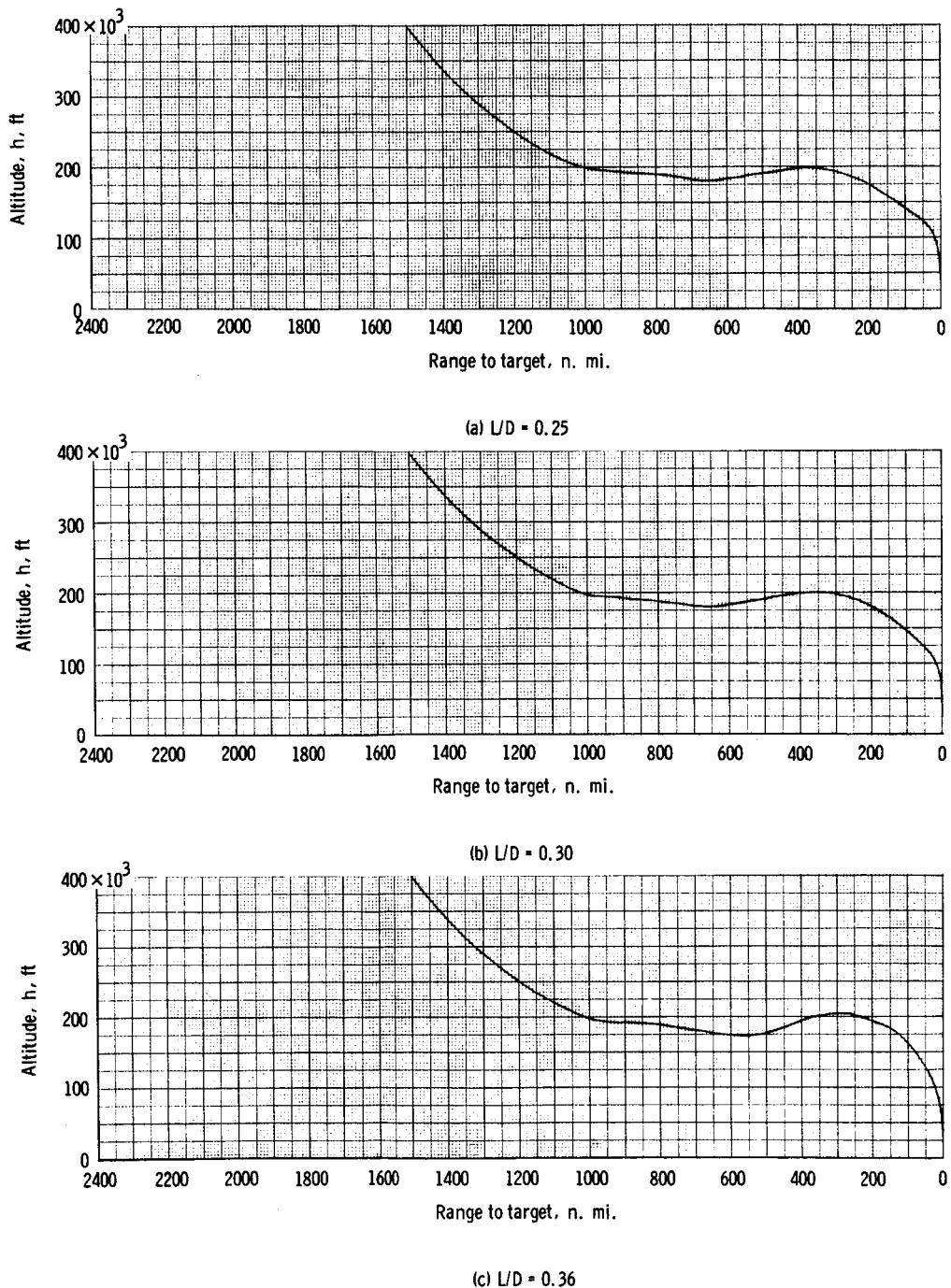


Figure 2. - Altitude versus range to target for a lunar return with a range to target at reentry of 1500 nautical miles and a flight-path angle of -5.7 degrees.

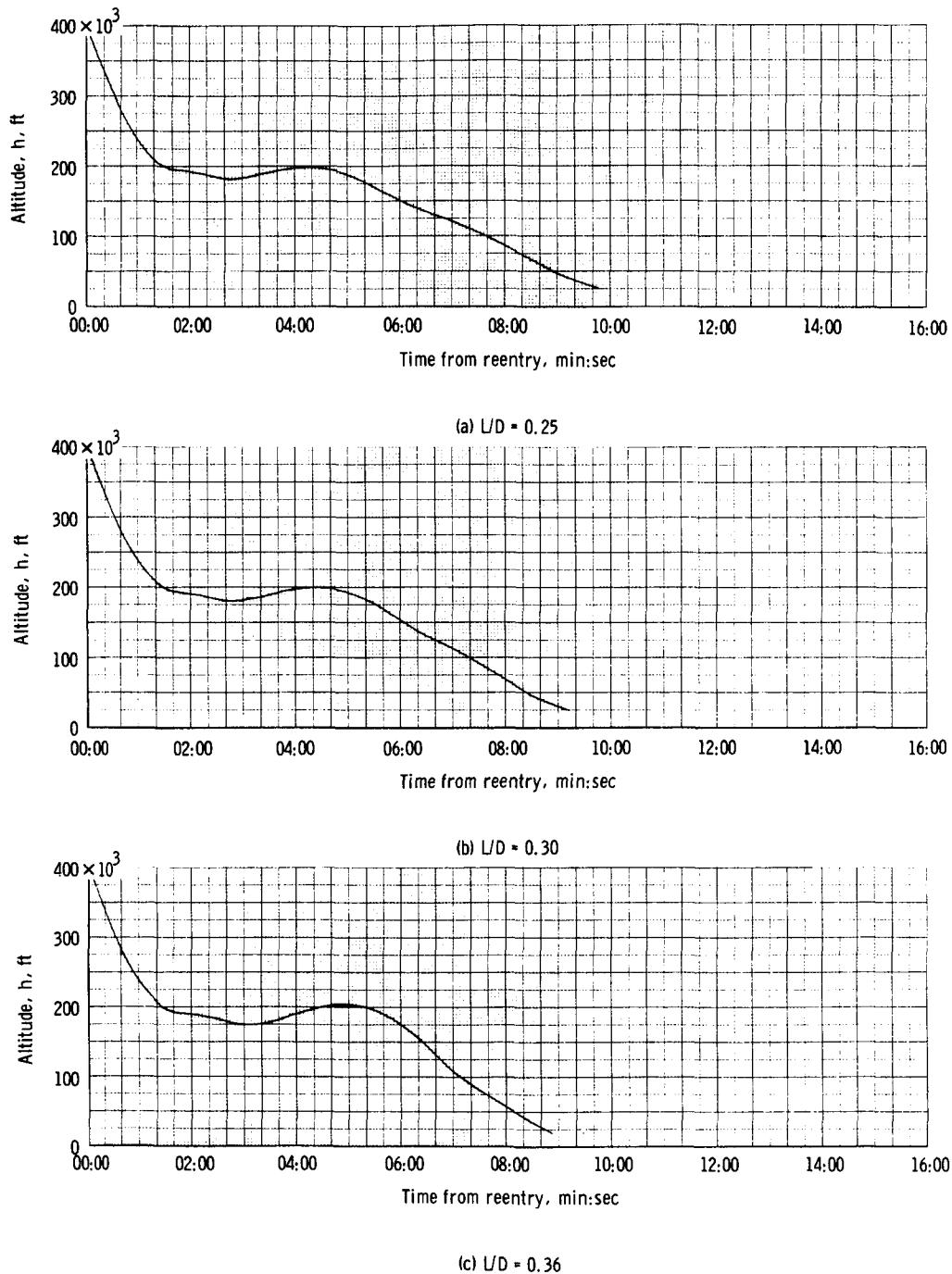


Figure 3. - Altitude versus time from reentry with reentry range of 1500 nautical miles and a flight-path angle of -5.7 degrees.

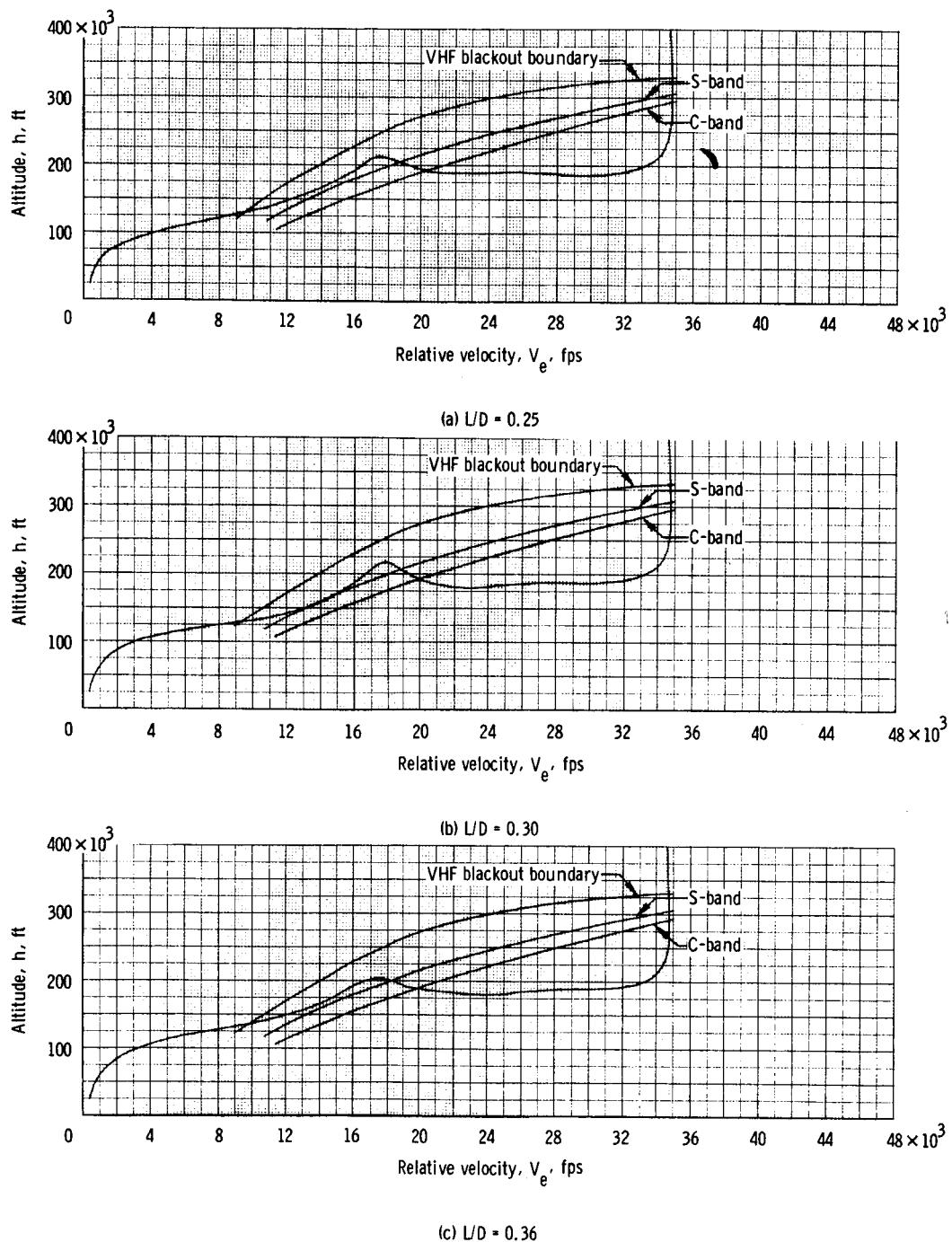


Figure 4. - Communications blackout region for lunar returns with a range to target at reentry of 1500 nautical miles and a flight-path angle of -6.30 degrees.

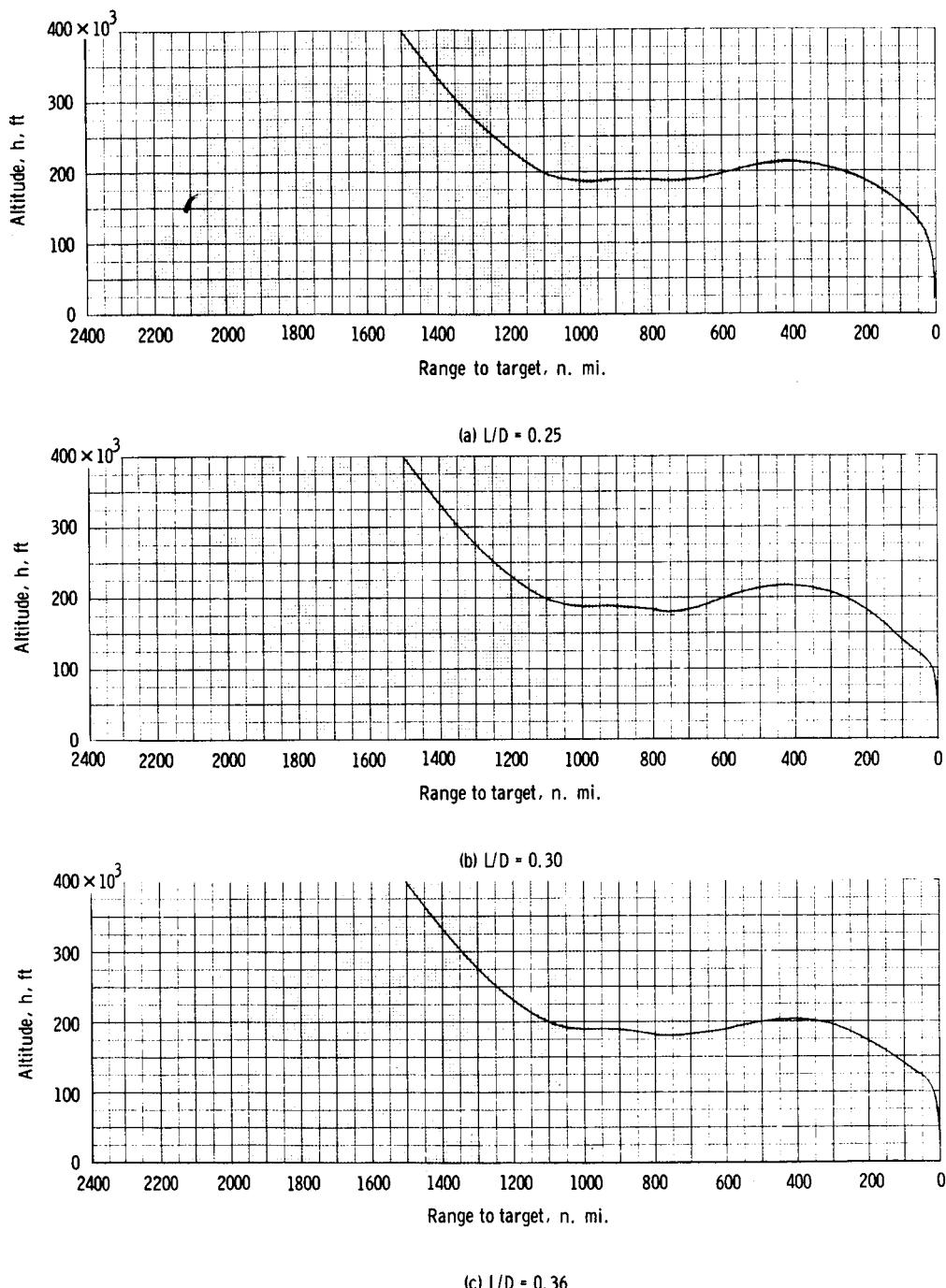


Figure 5. - Altitude versus range to target for a lunar return with a range to target at reentry of 1500 nautical miles and a flight-path angle of -6.30 degrees.

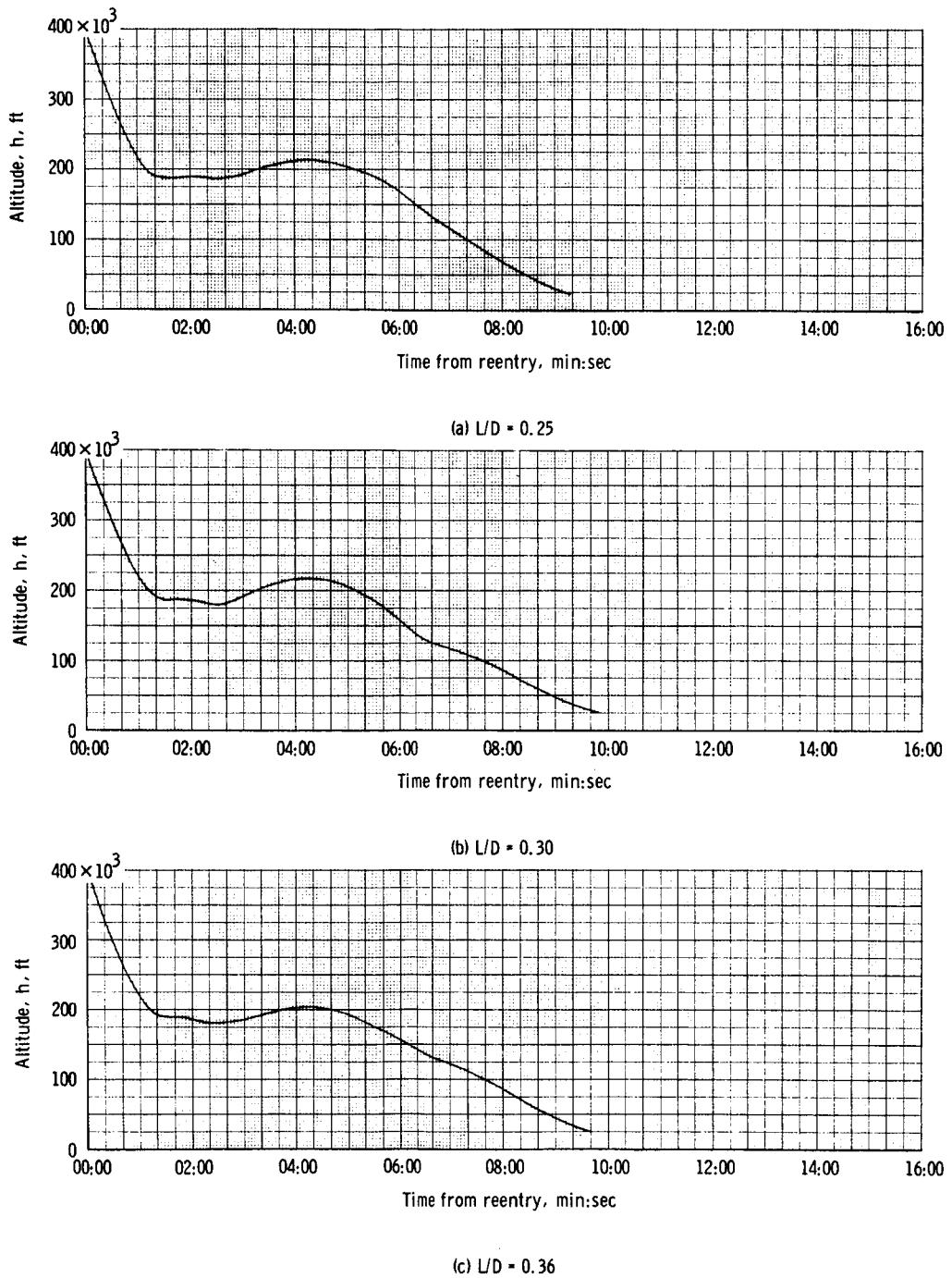


Figure 6. - Altitude versus time from reentry with reentry range of 1500 nautical miles and a flight-path angle of -6.30 degrees.

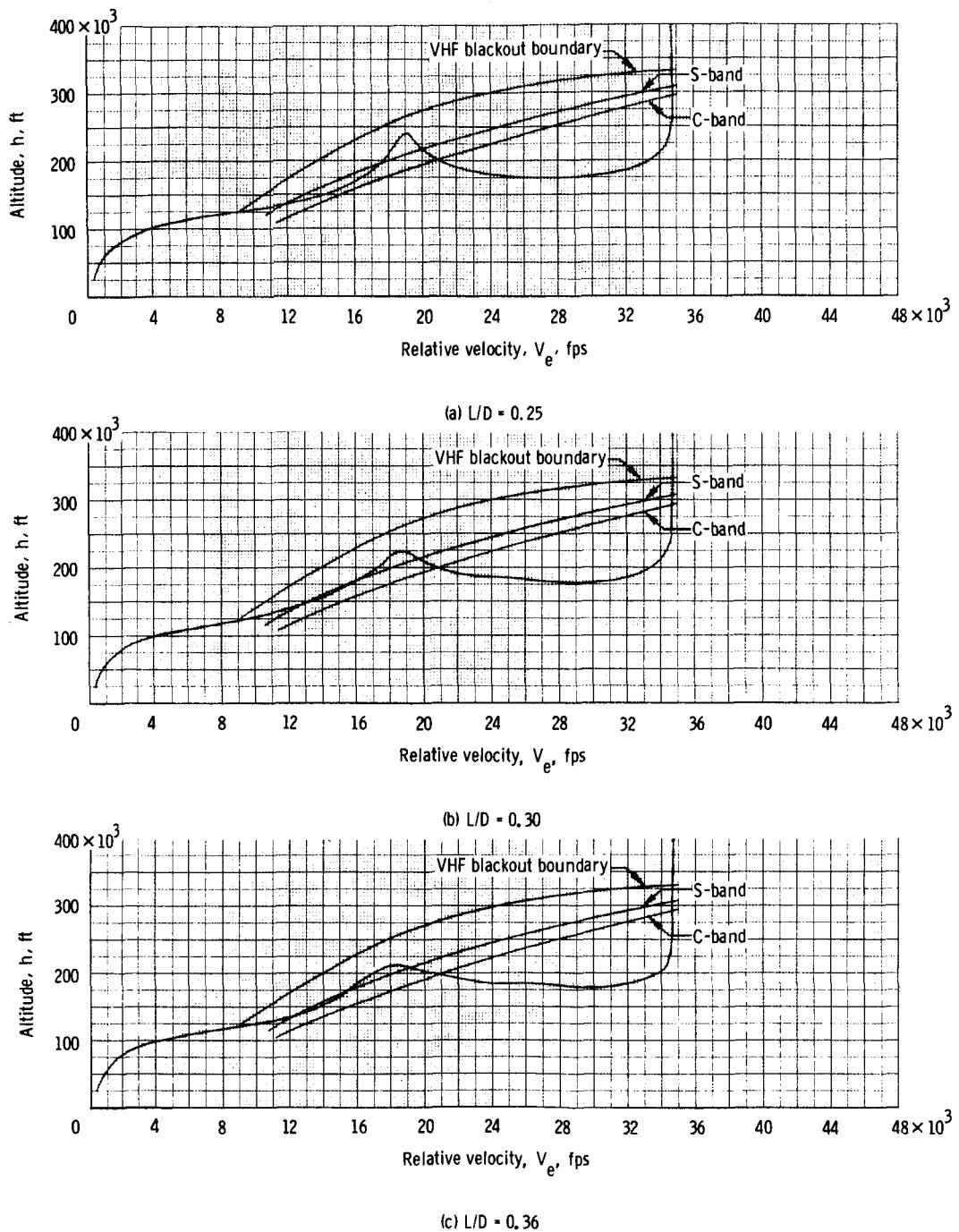


Figure 7. - Communications blackout region for lunar returns with a range to target at reentry of 1500 nautical miles and a flight-path angle of -6.70 degrees.

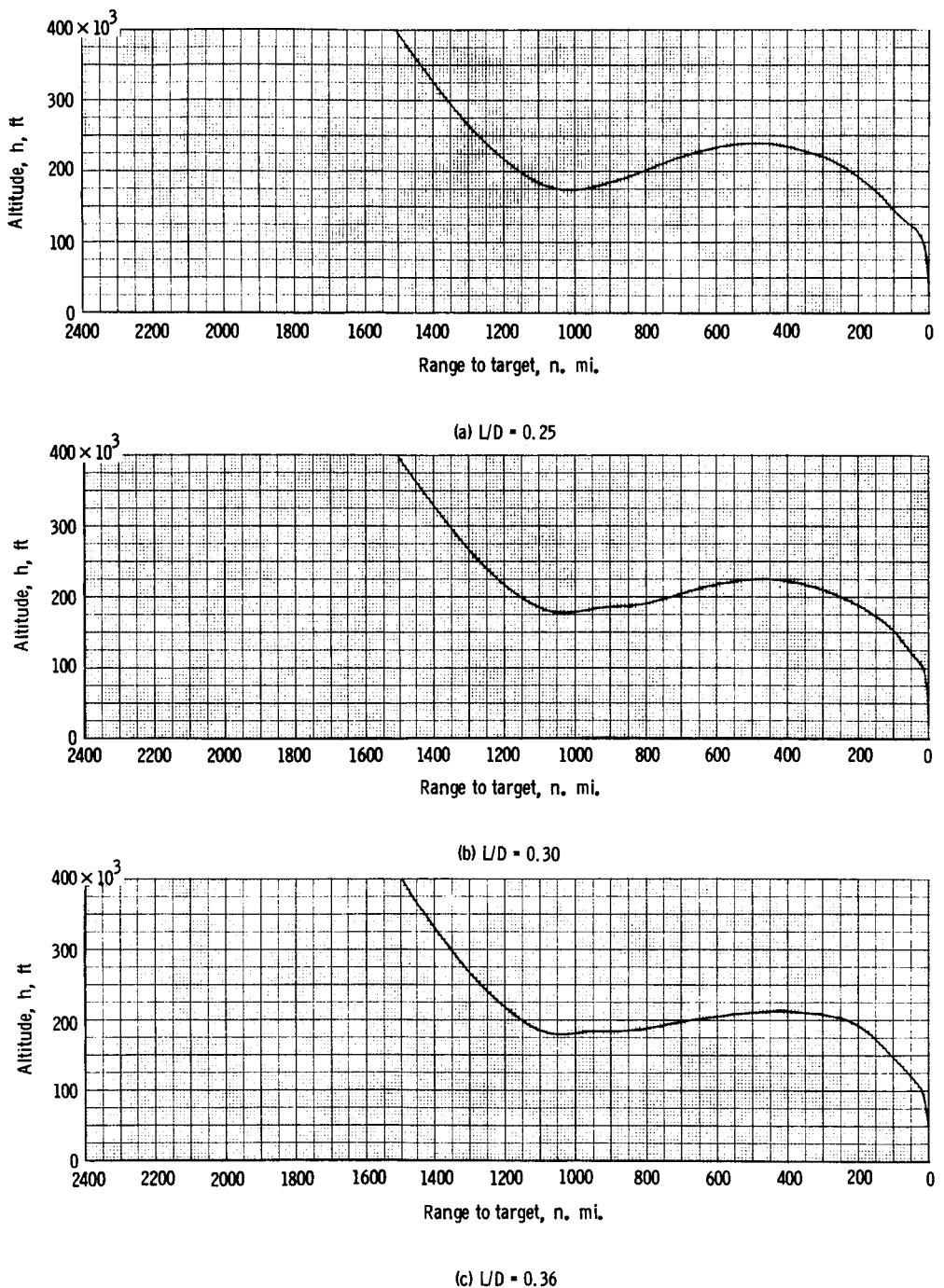


Figure 8.- Altitude versus range to target for a lunar return with a range to target at reentry of 1500 nautical miles and a flight-path angle of -6.70 degrees.

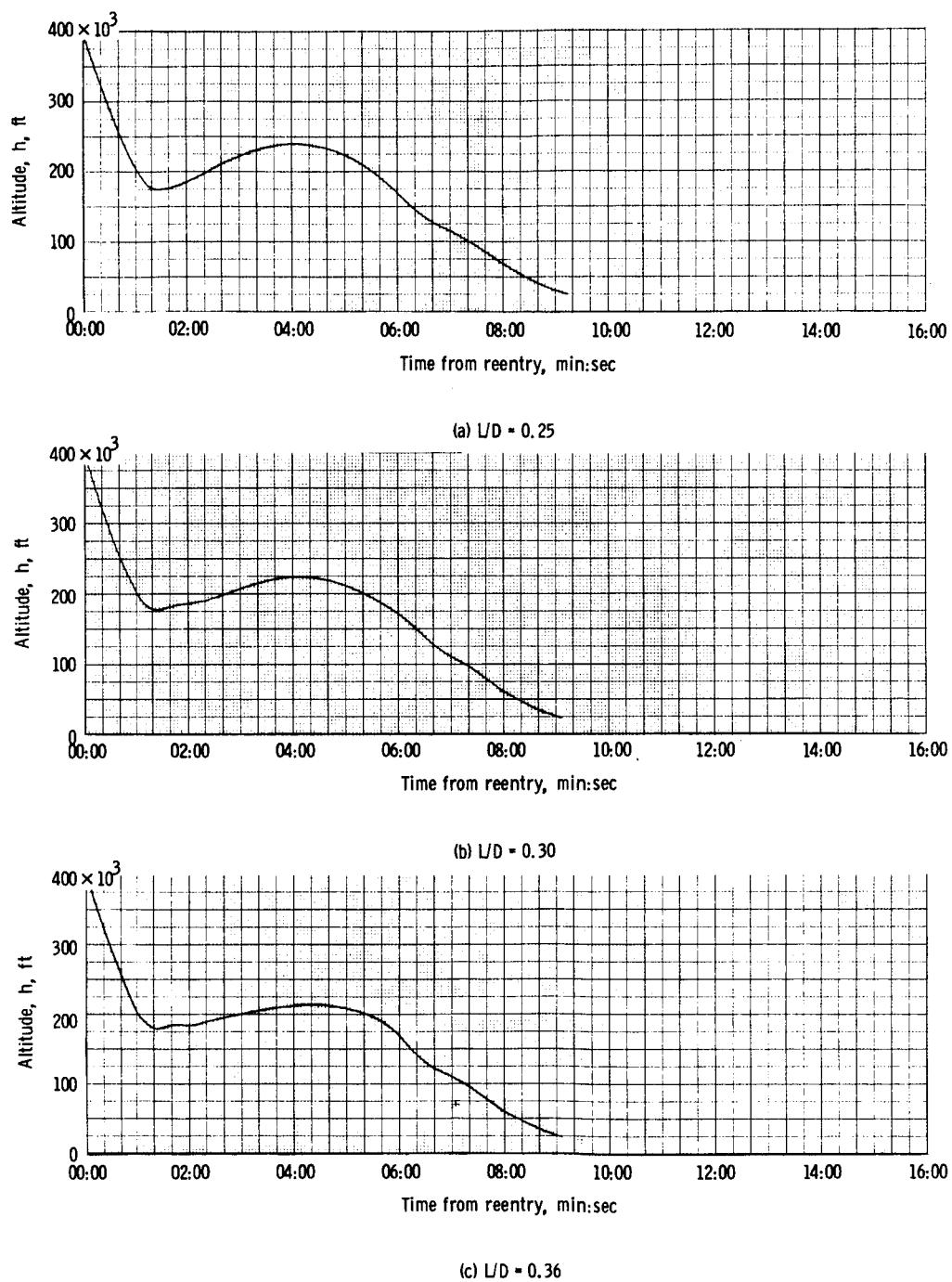


Figure 9. - Altitude versus time from reentry with reentry range of 1500 nautical miles and a flight-path angle of -6.70 degrees.

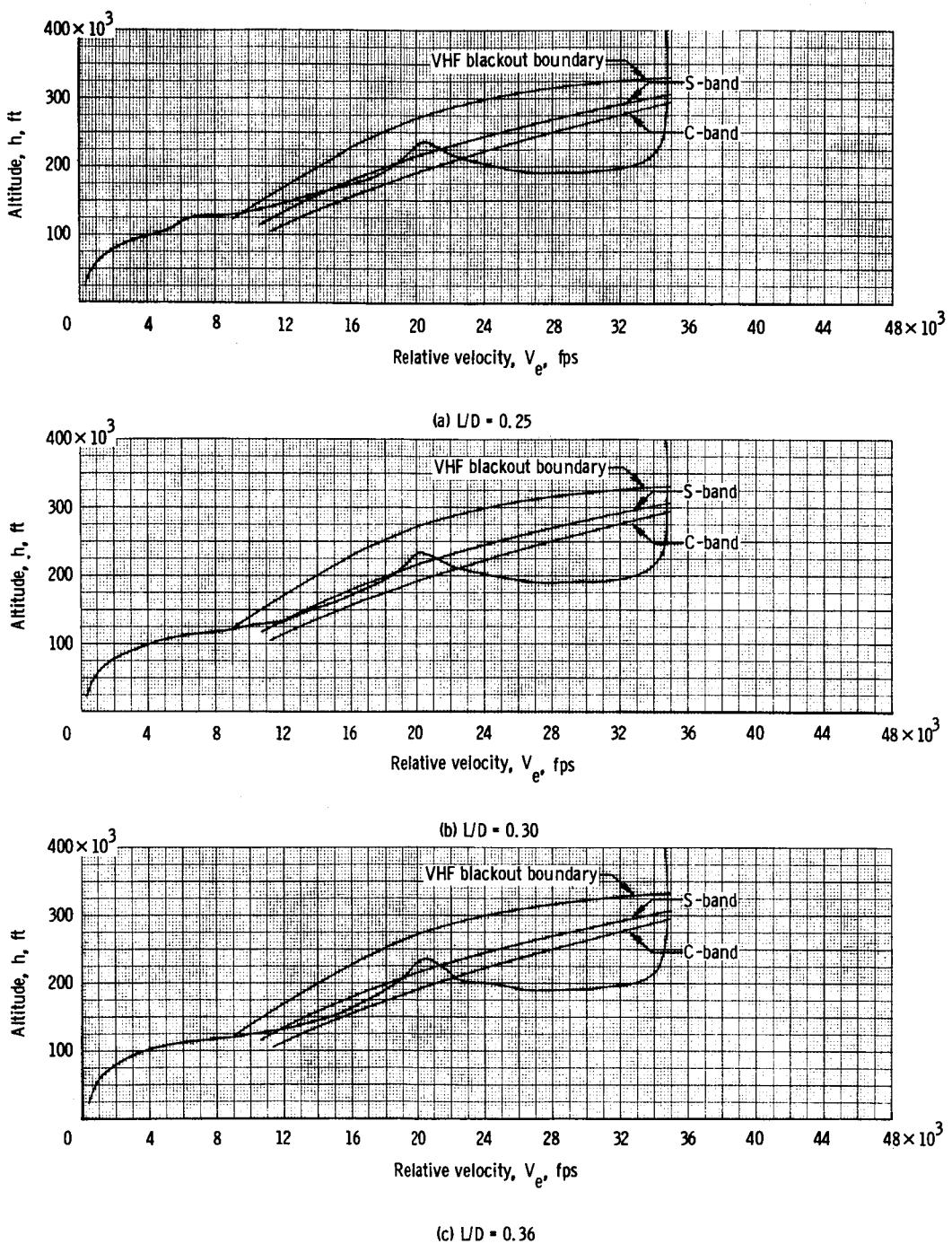


Figure 10. - Communications blackout region for lunar returns with a range to target at reentry of 2000 nautical miles and a flight-path angle of -5.7 degrees.

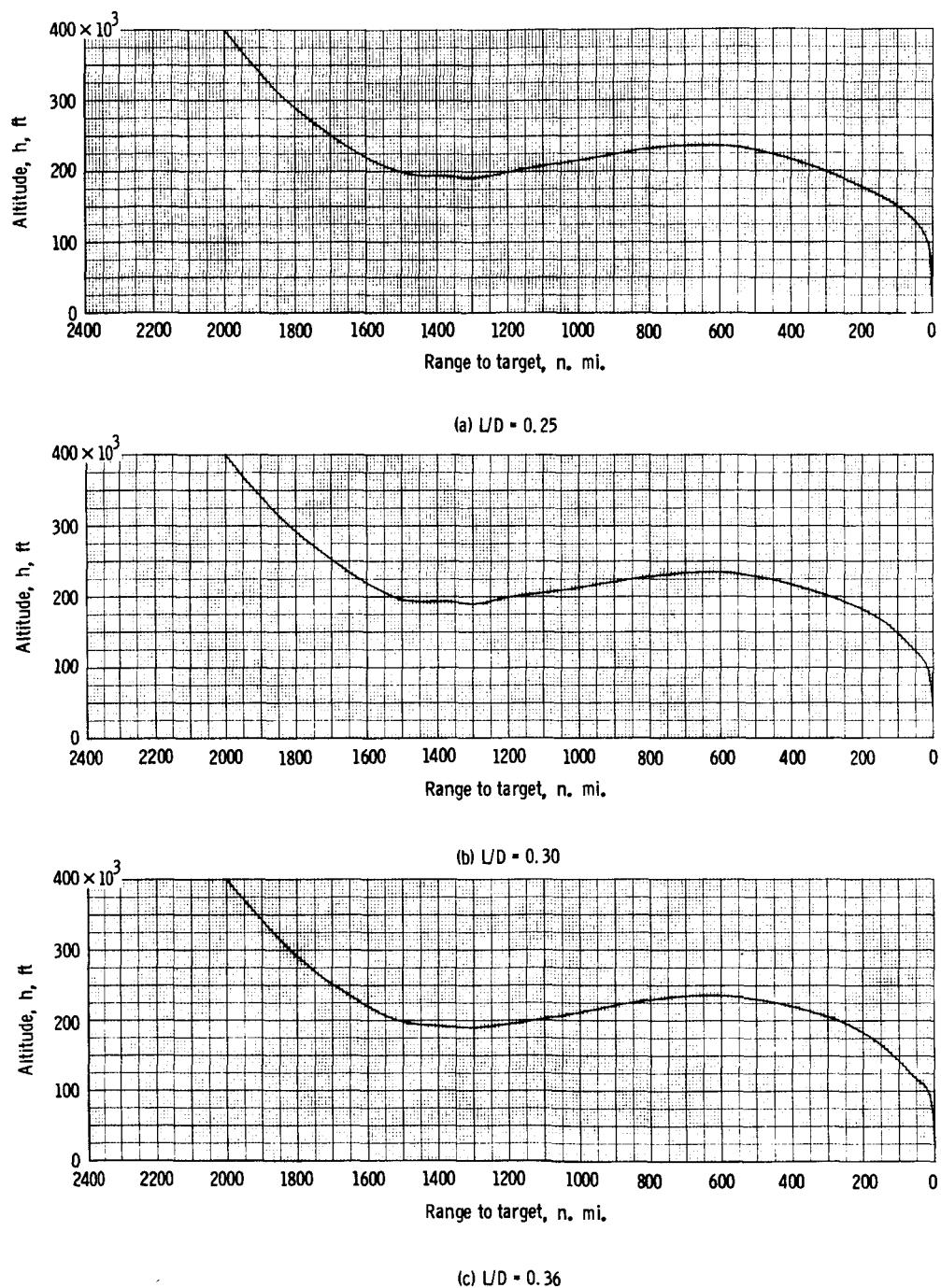


Figure 11. - Altitude versus range to target for a lunar return with a range to target at reentry of 2000 nautical miles and a flight-path angle of -5.7 degrees.

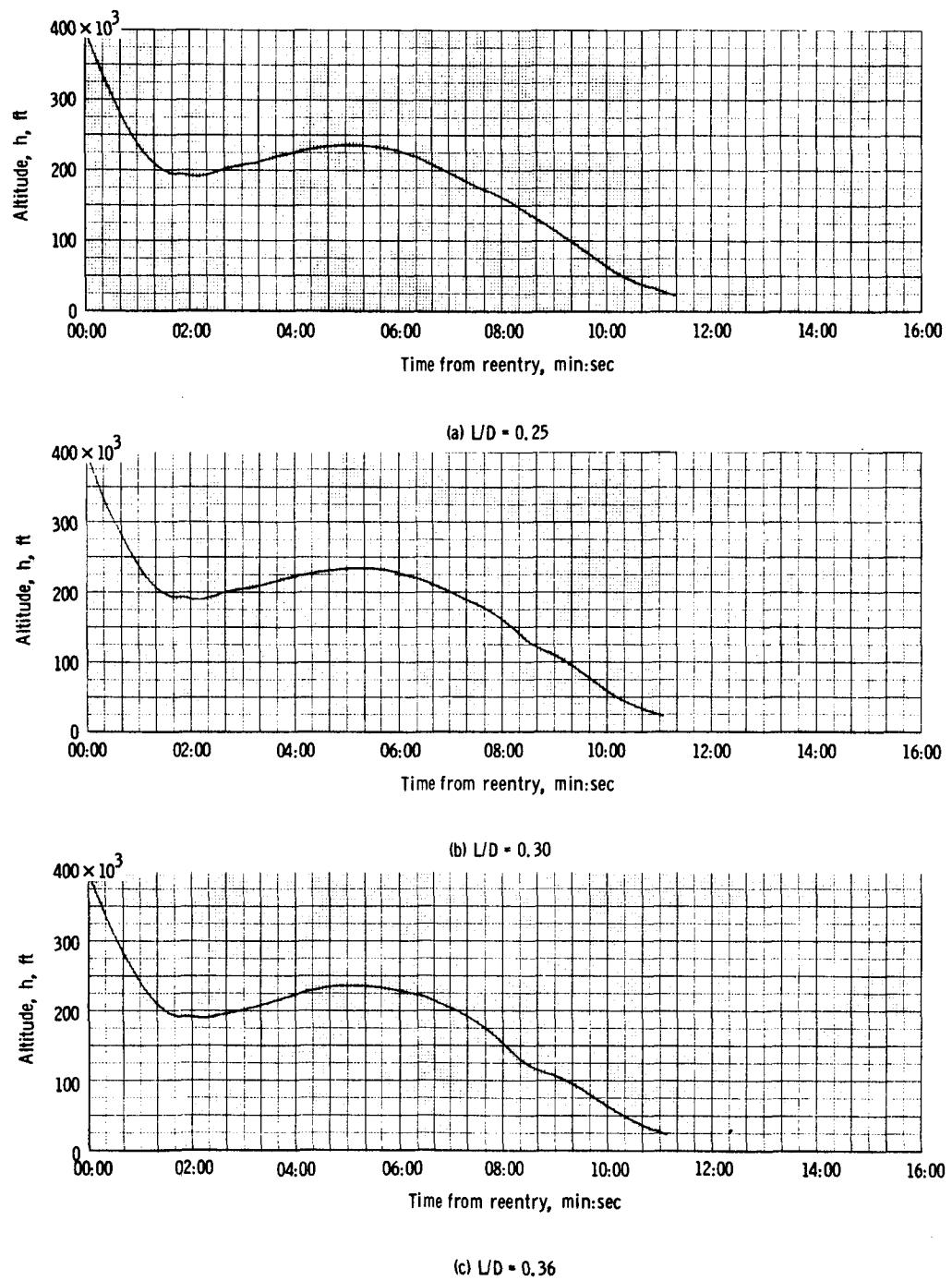


Figure 12. - Altitude versus time from reentry with reentry range of 2000 nautical miles and a flight-path angle of -5.7 degrees.

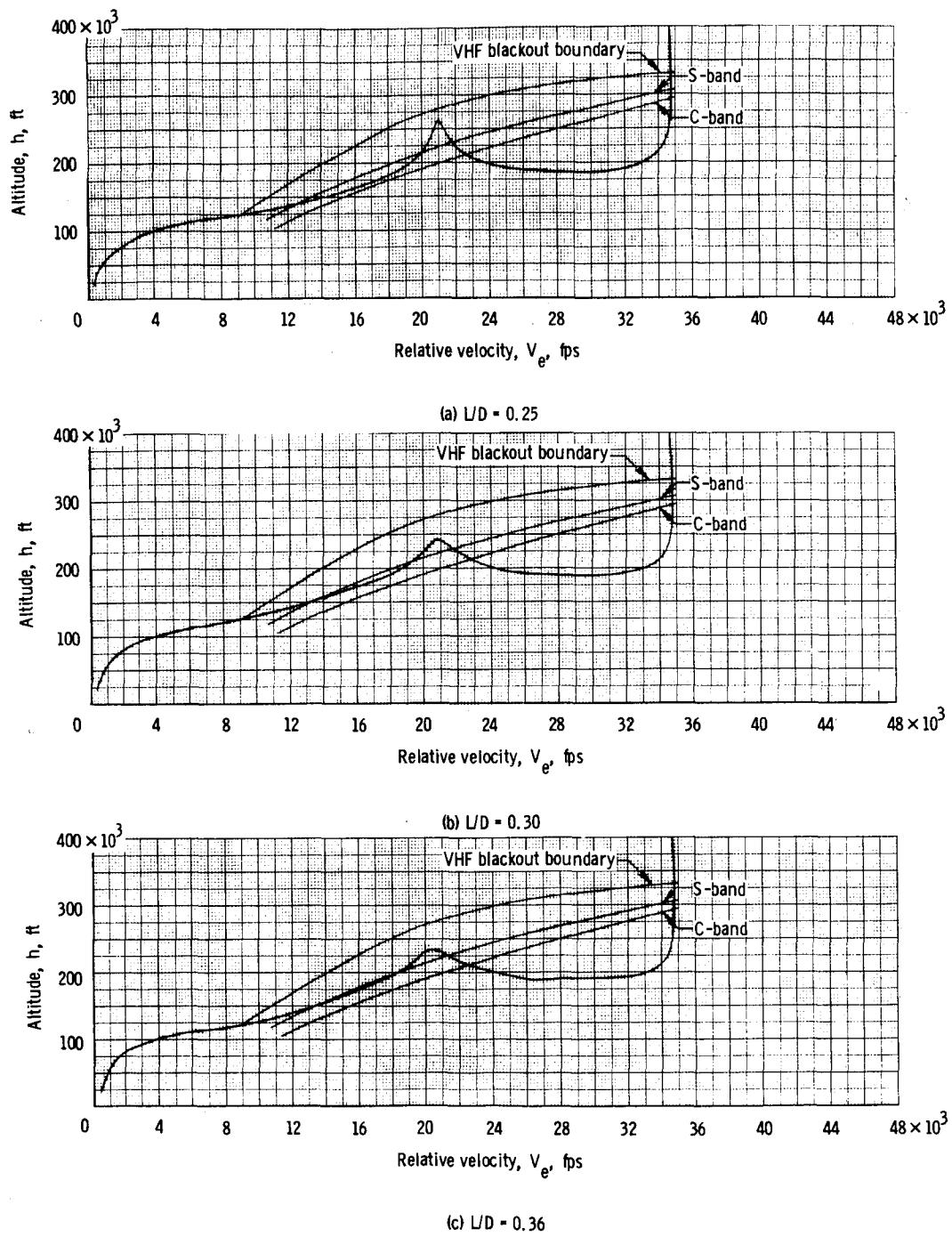


Figure 13. - Communications blackout region for lunar returns with a range to target at reentry of 2000 nautical miles and a flight-path angle of -6.30 degrees.

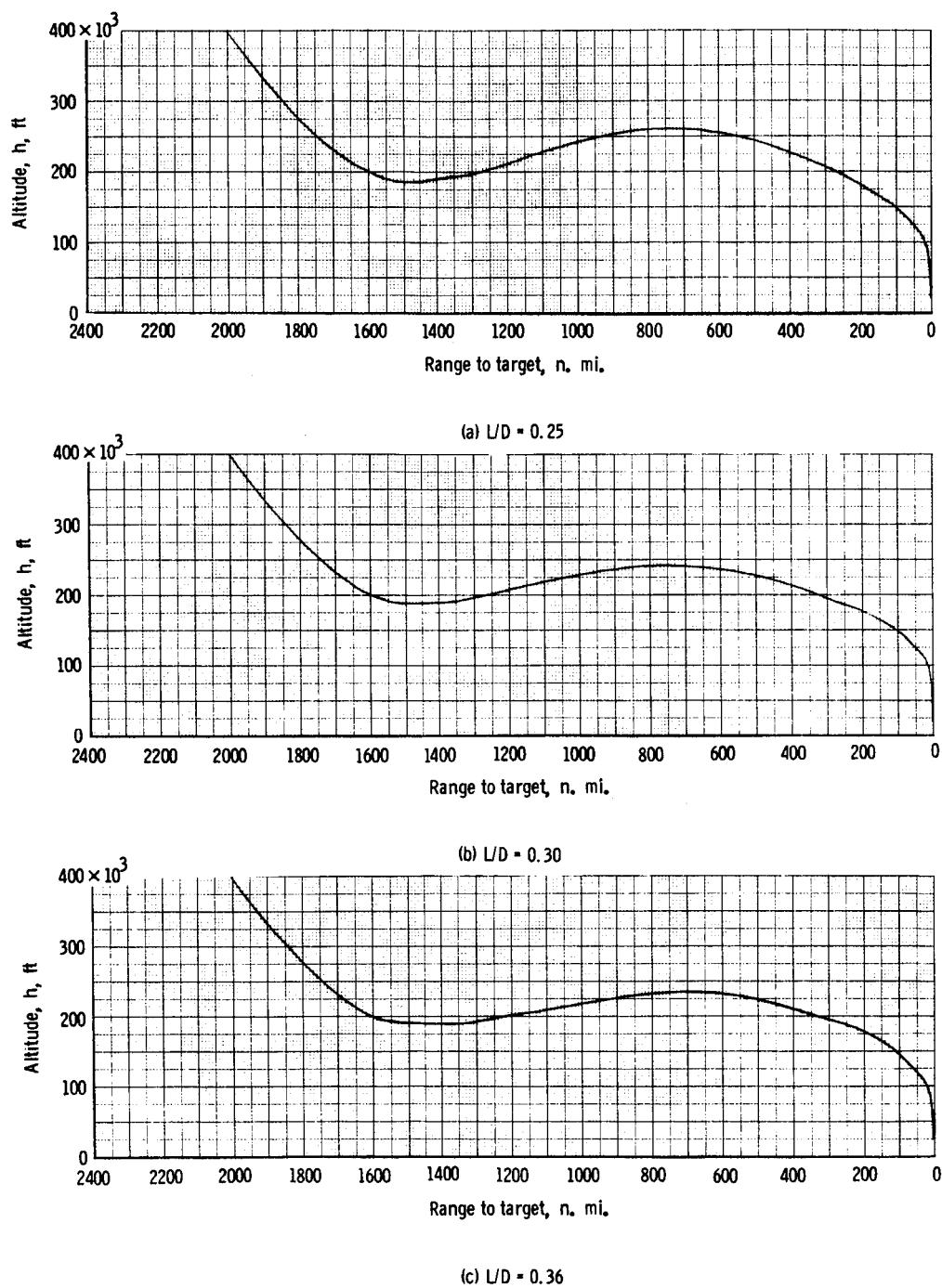


Figure 14. - Altitude versus range to target for a lunar return with a range to target at reentry of 2000 nautical miles and a flight-path angle of -6.30 degrees.

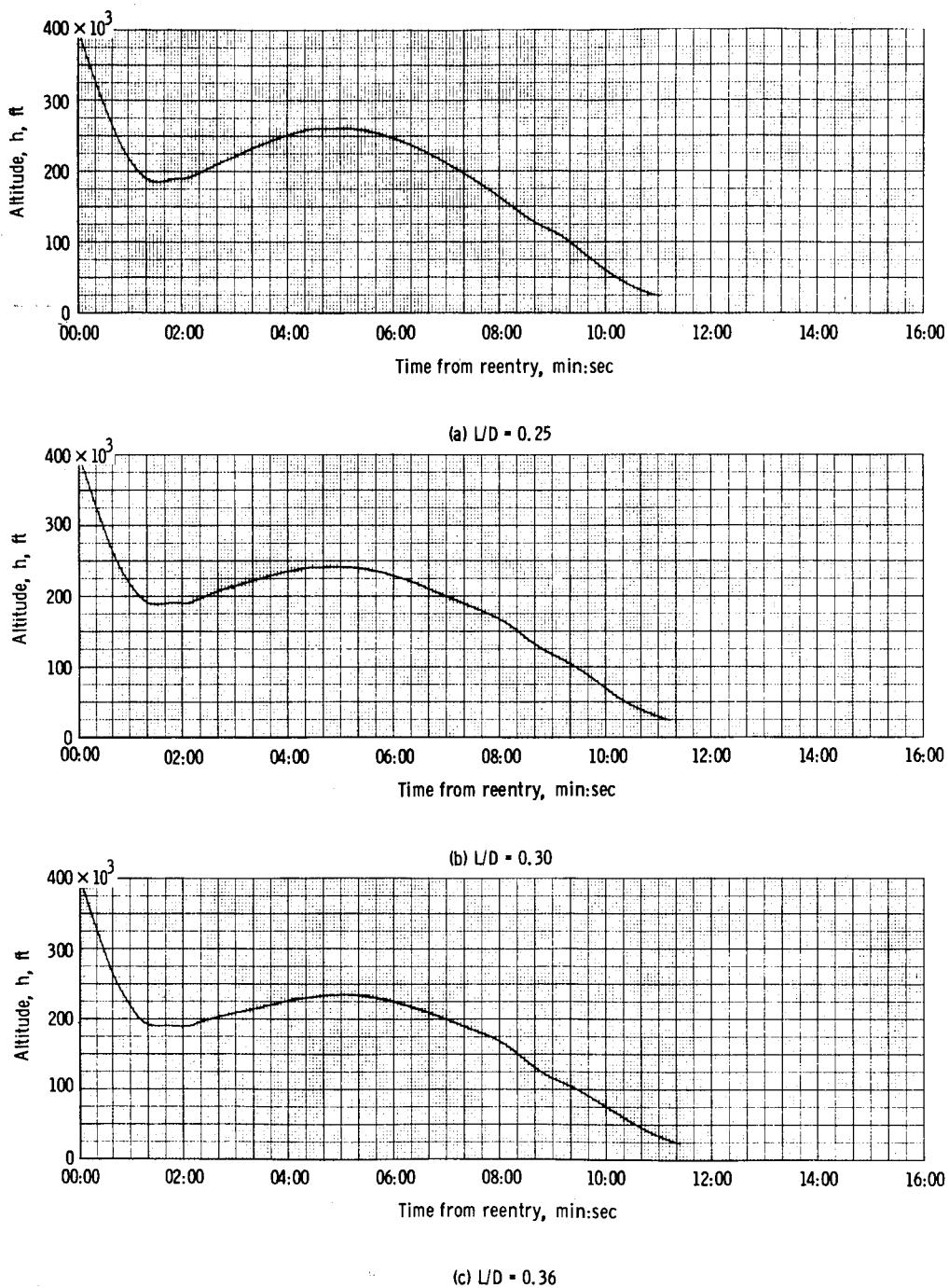


Figure 15. - Altitude versus time from reentry with reentry range of 2000 nautical miles and a flight-path angle of  $-6.30$  degrees.

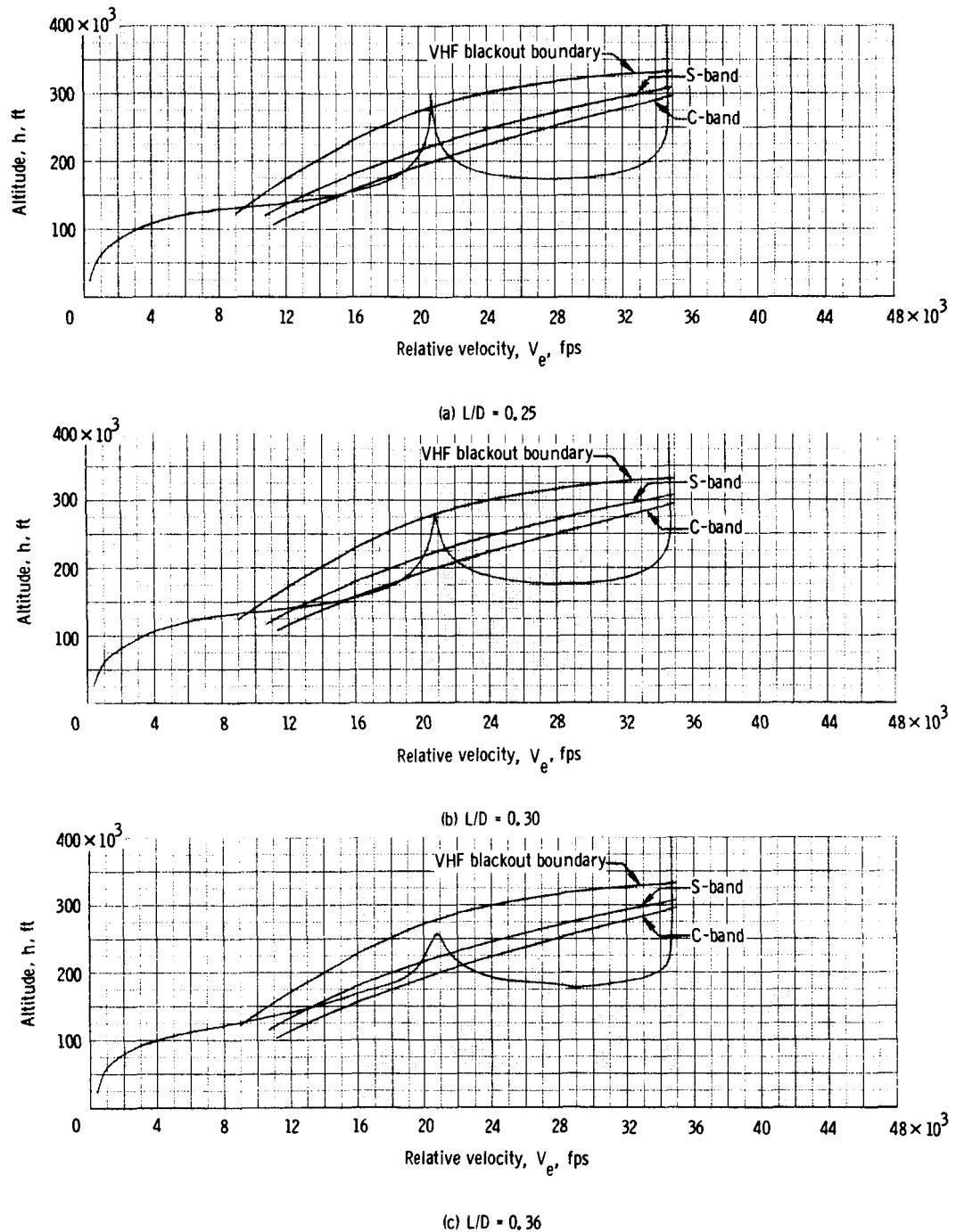


Figure 16. - Communications blackout region for lunar returns with a range to target at reentry of 2000 nautical miles and a flight-path angle of -6, 70 degrees.

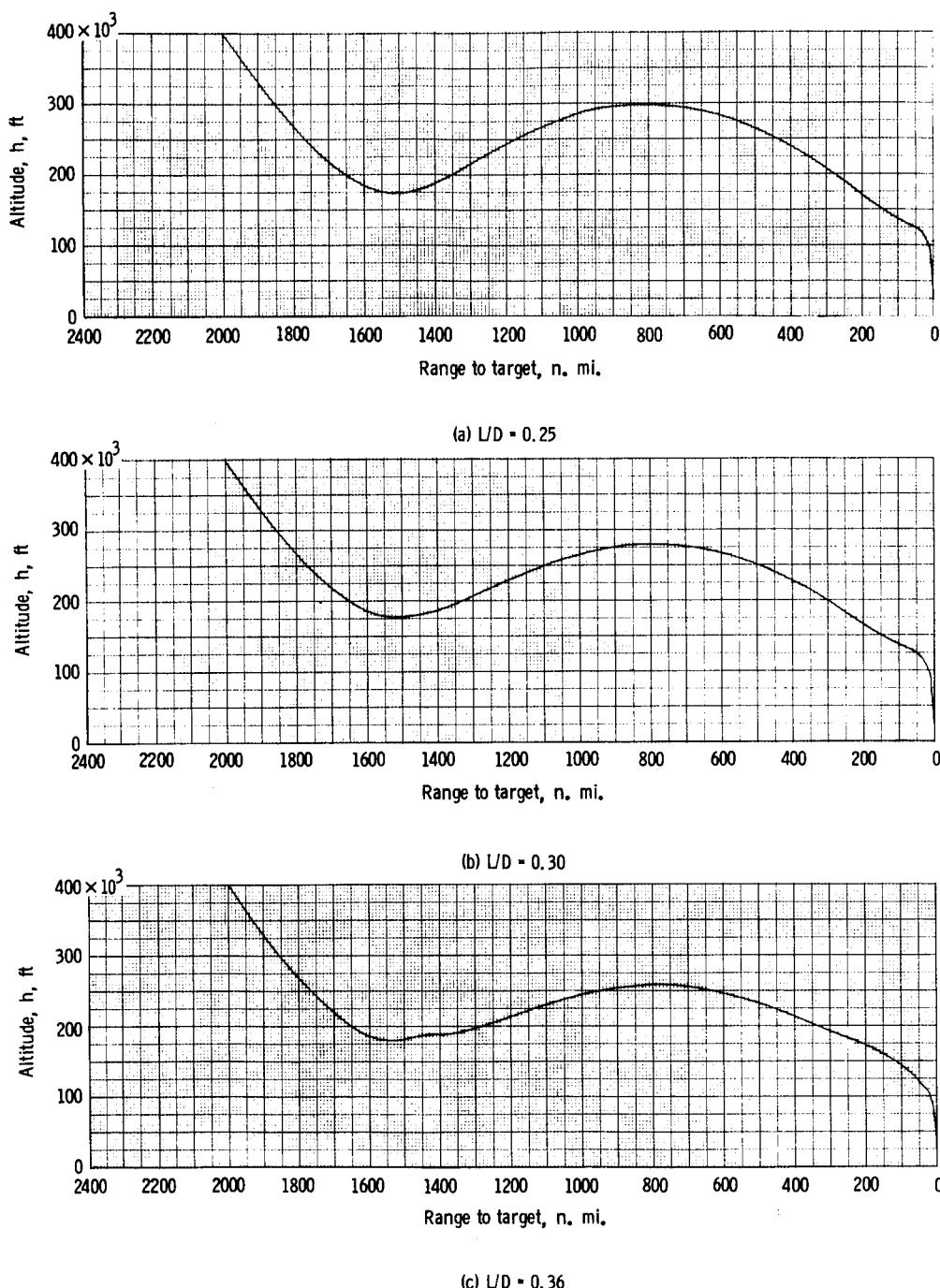


Figure 17. - Altitude versus range to target for a lunar return with a range to target at reentry of 2000 nautical miles and a flight-path angle of -6.70 degrees.

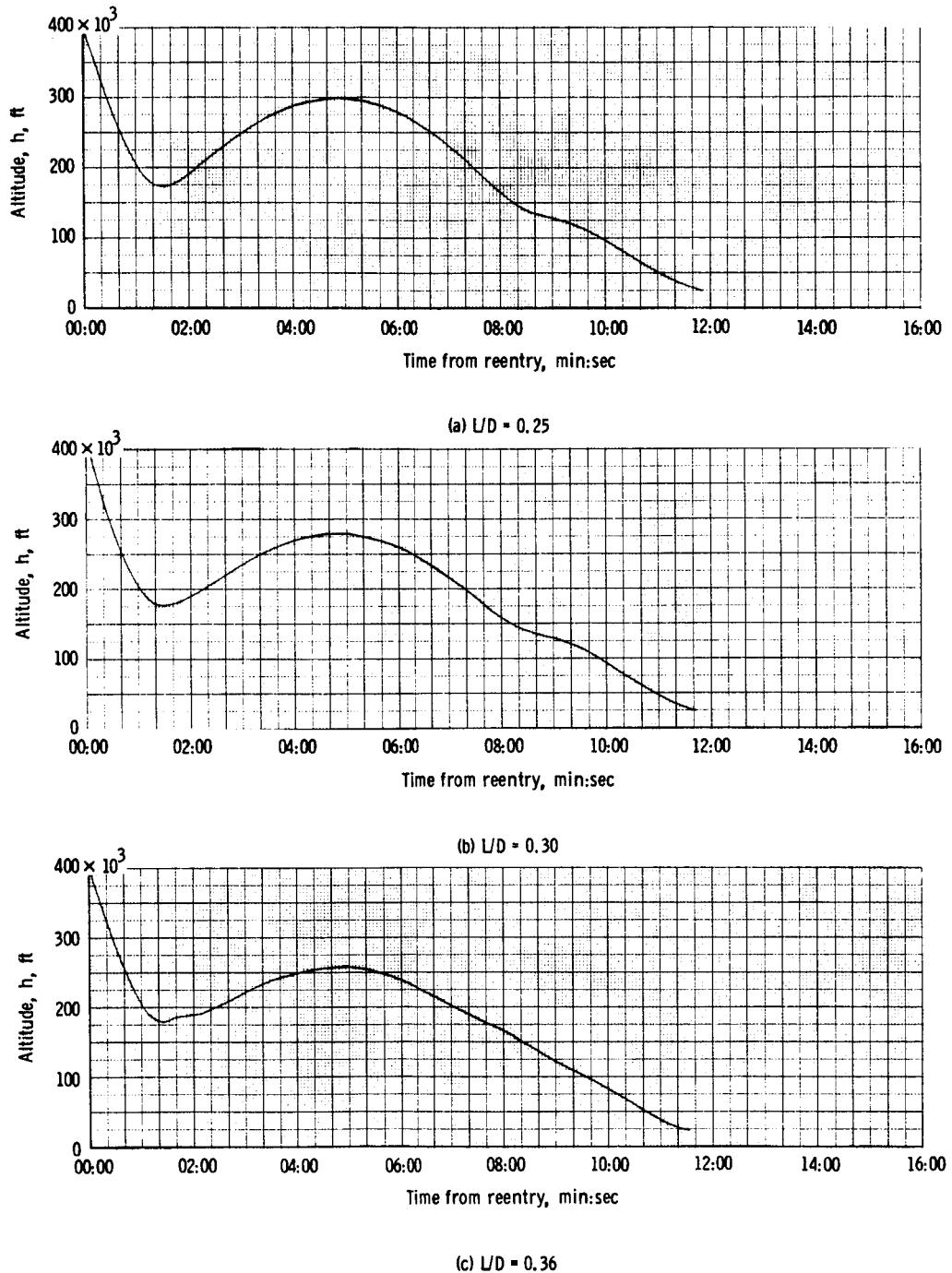


Figure 18.- Altitude versus time from reentry with reentry range of 2000 nautical miles and a flight-path angle of -6.70 degrees.

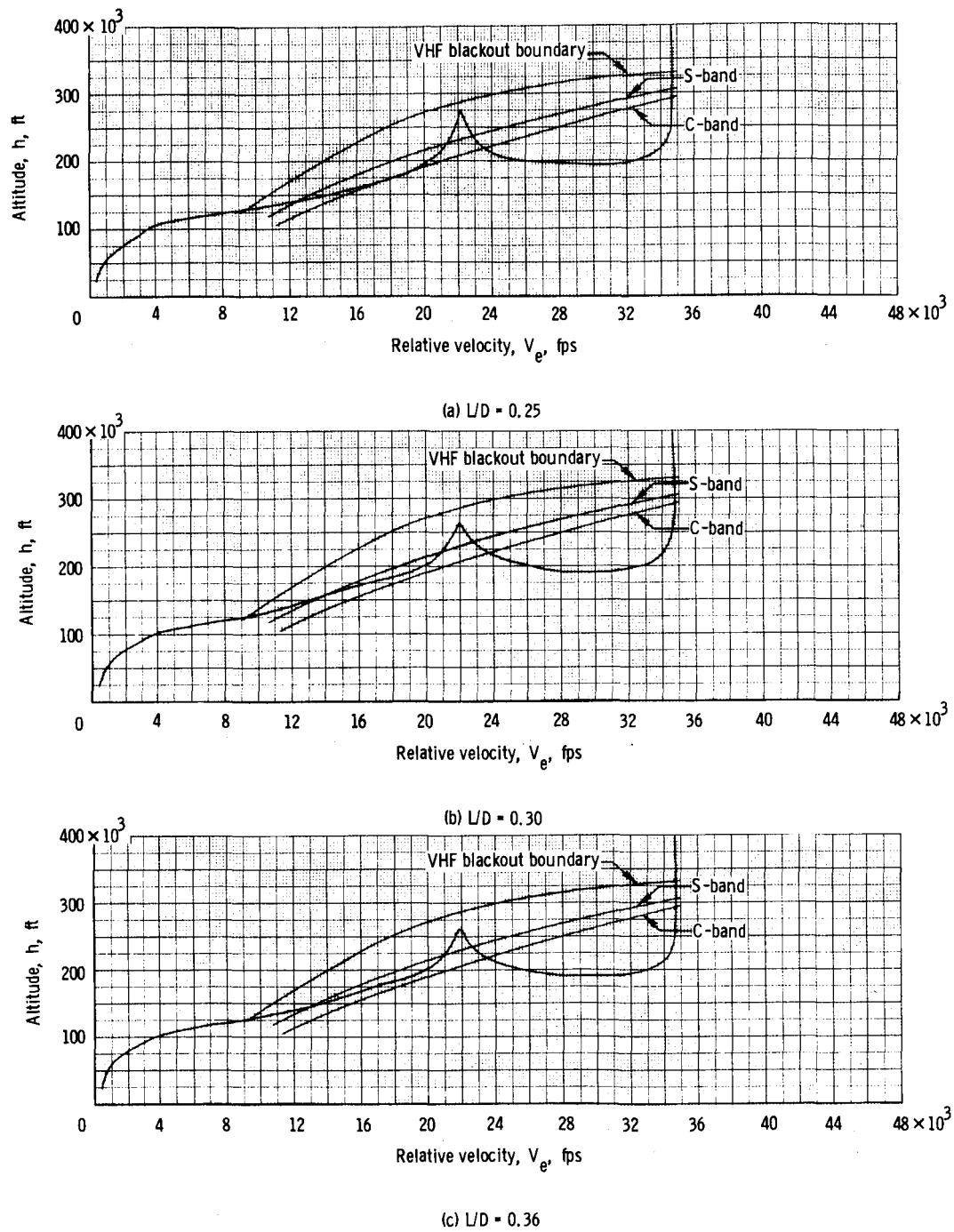


Figure 19. - Communications blackout region for lunar returns with a range to target at reentry of 2500 nautical miles and a flight-path angle of -5.7 degrees.

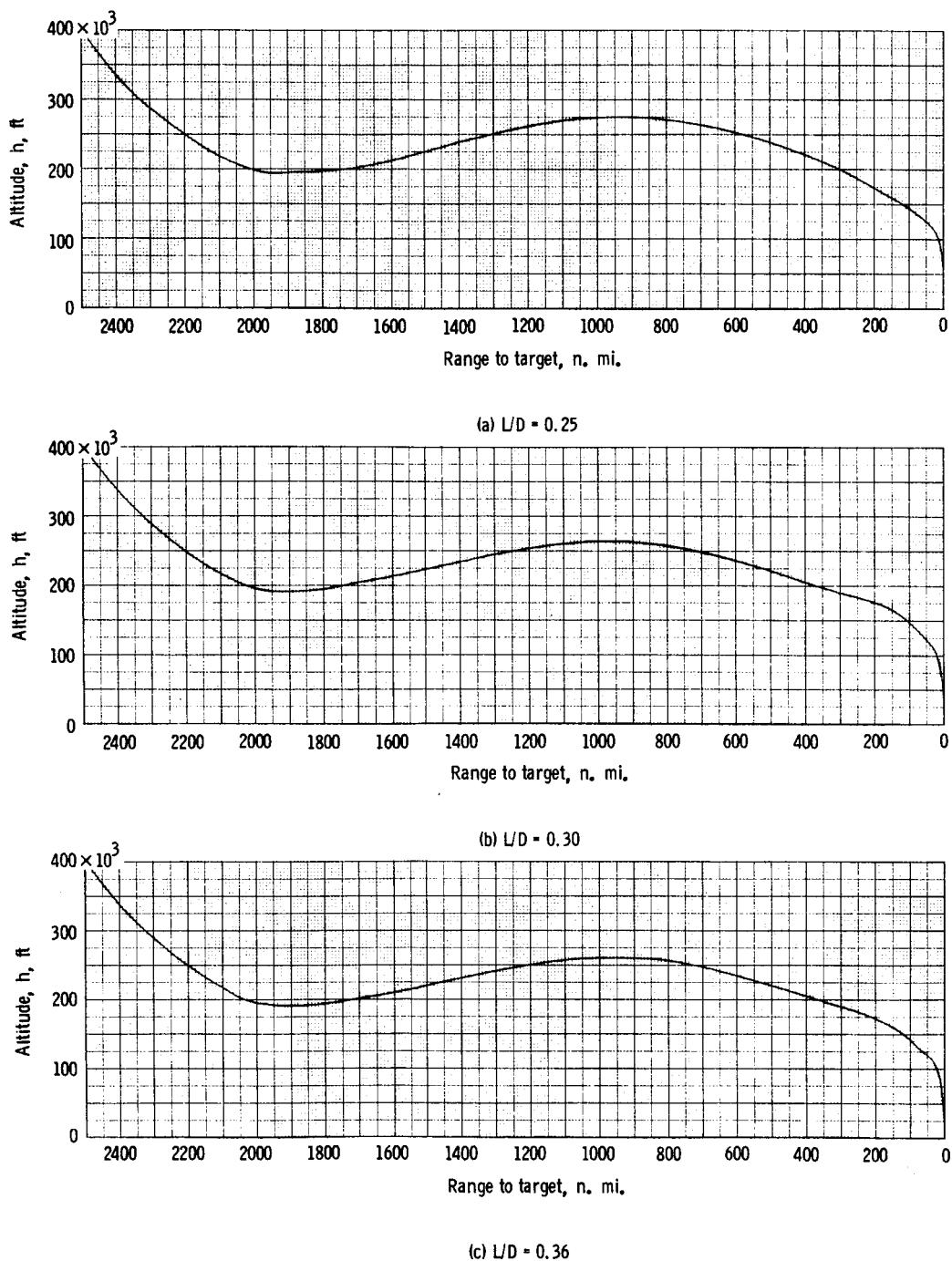


Figure 20. - Altitude versus range to target for a lunar return with a range to target at reentry of 2500 nautical miles and a flight-path angle of -5.7 degrees.

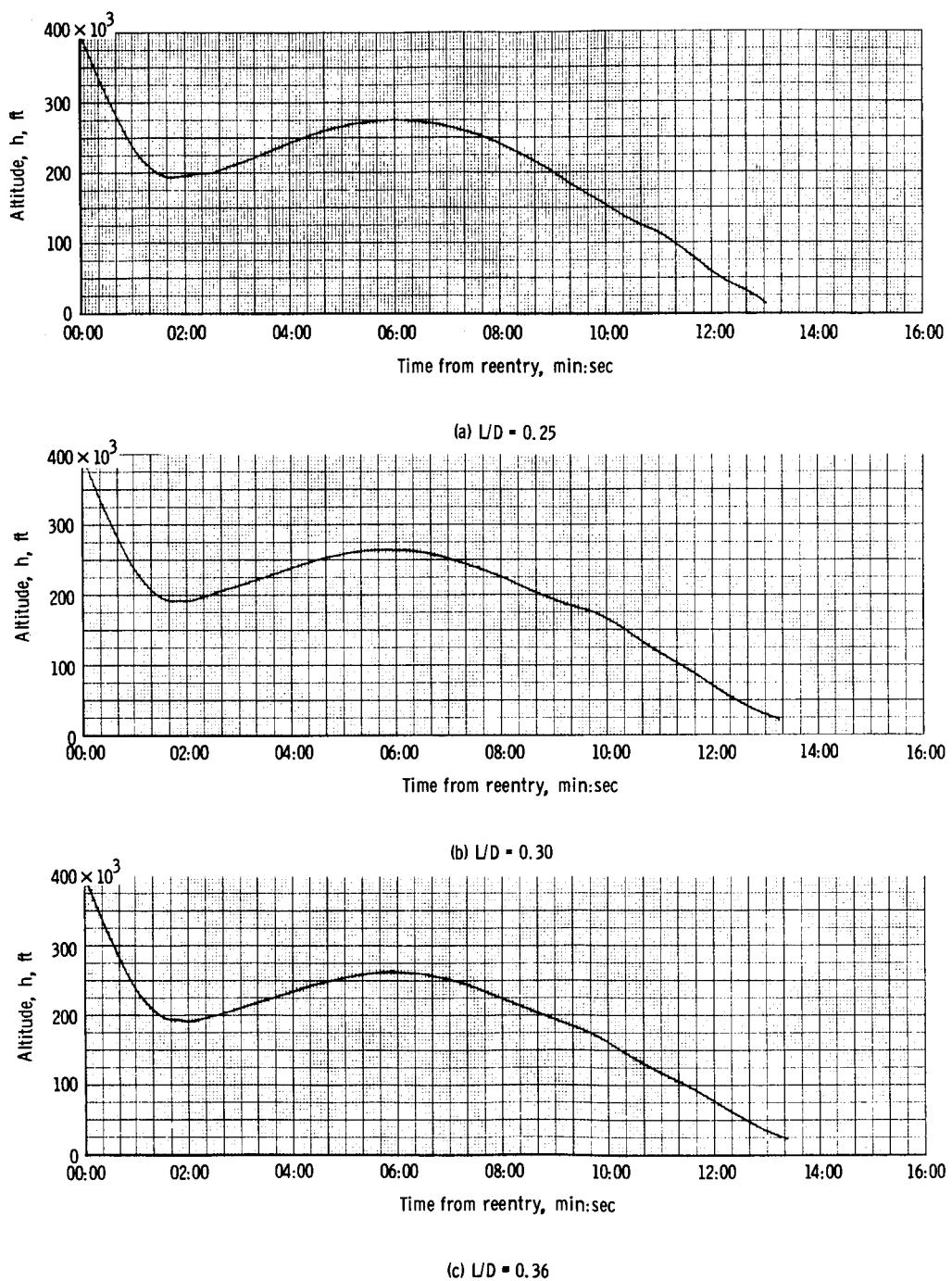


Figure 21. - Altitude versus time from reentry with reentry range of 2500 nautical miles and a flight-path angle of -5.7 degrees.

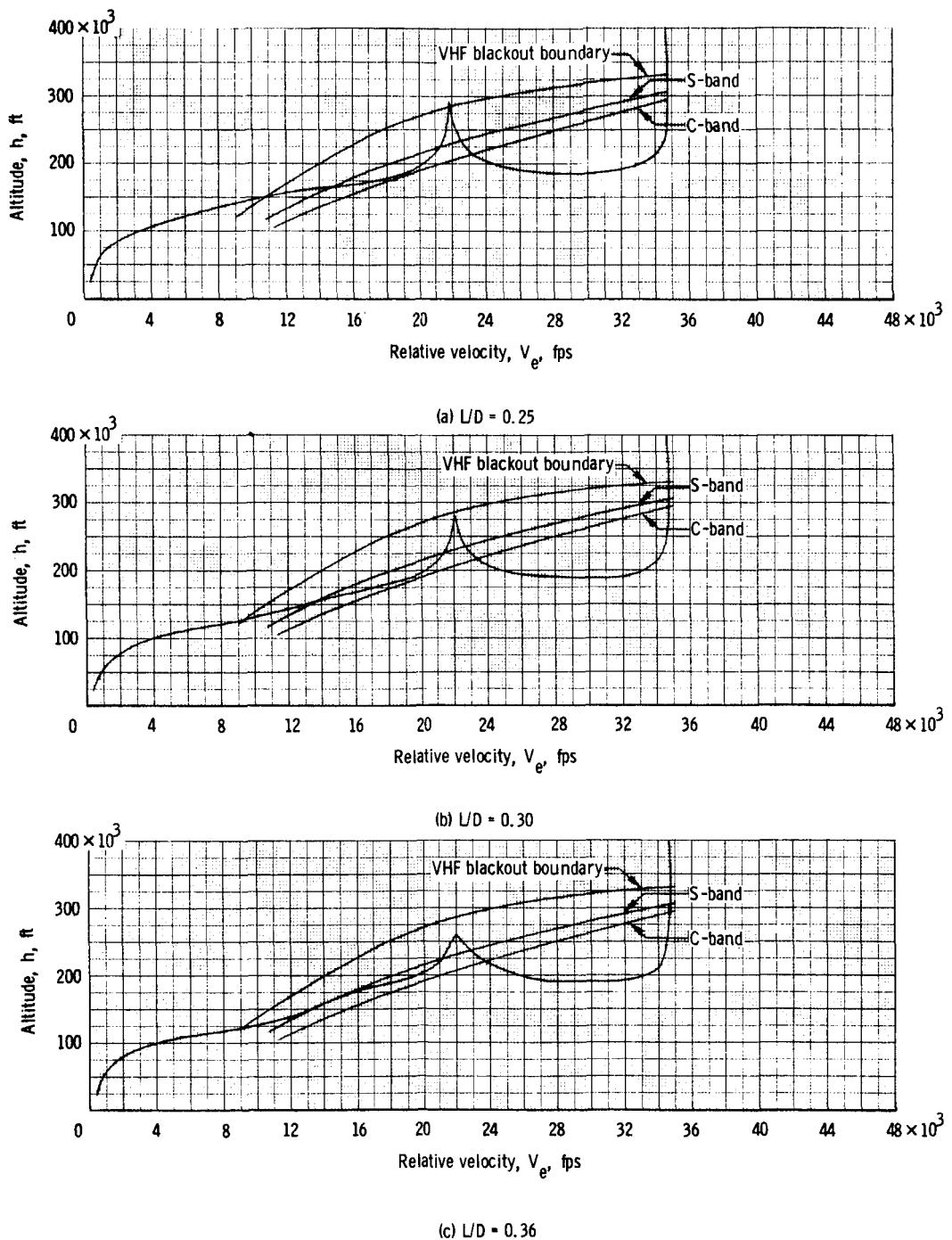


Figure 22. - Communications blackout region for lunar returns with a range to target at reentry of 2500 nautical miles and a flight-path angle of -6.30 degrees.

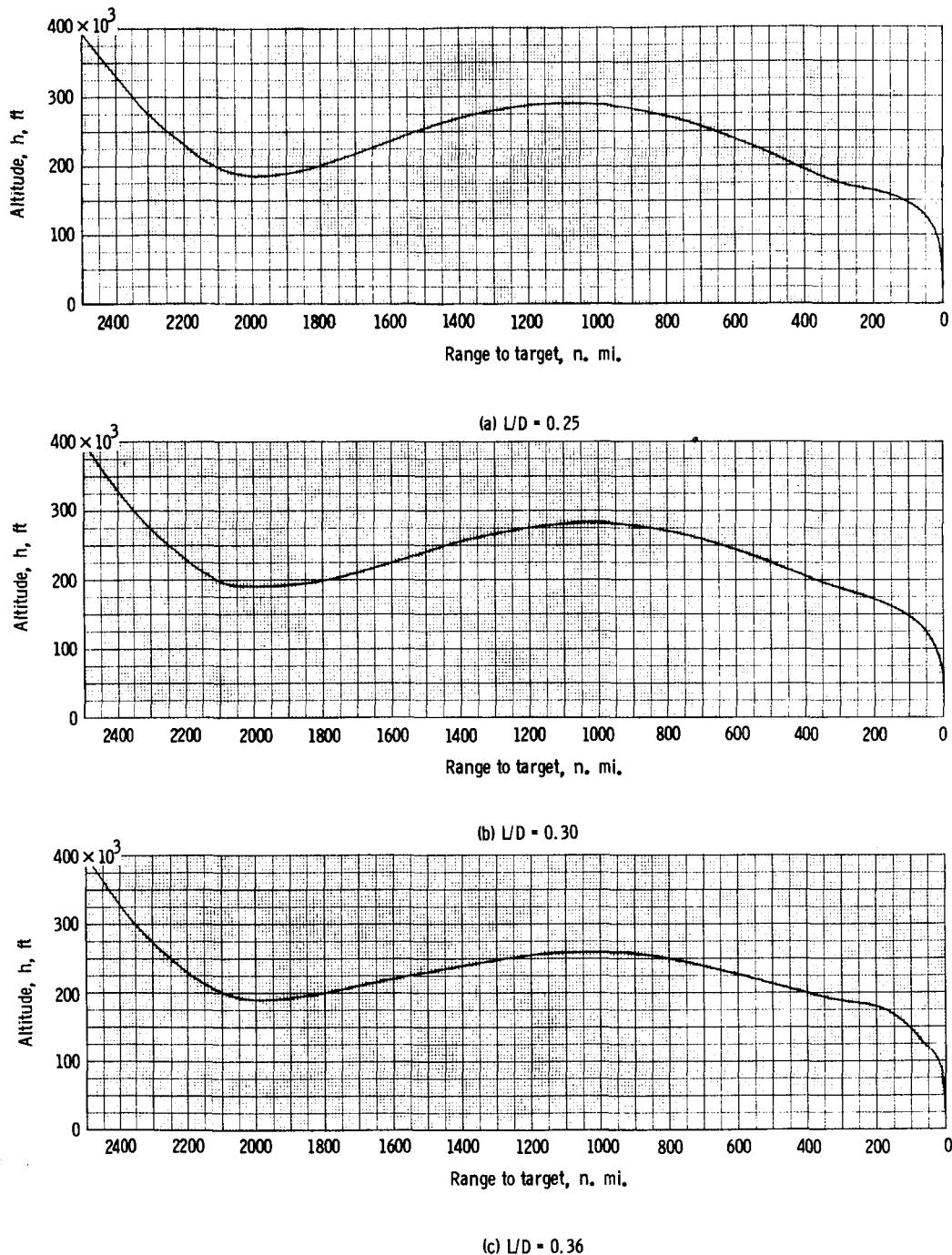


Figure 23. - Altitude versus range to target for a lunar return with a range to target at reentry of 2500 nautical miles and a flight-path angle of -6.30 degrees.

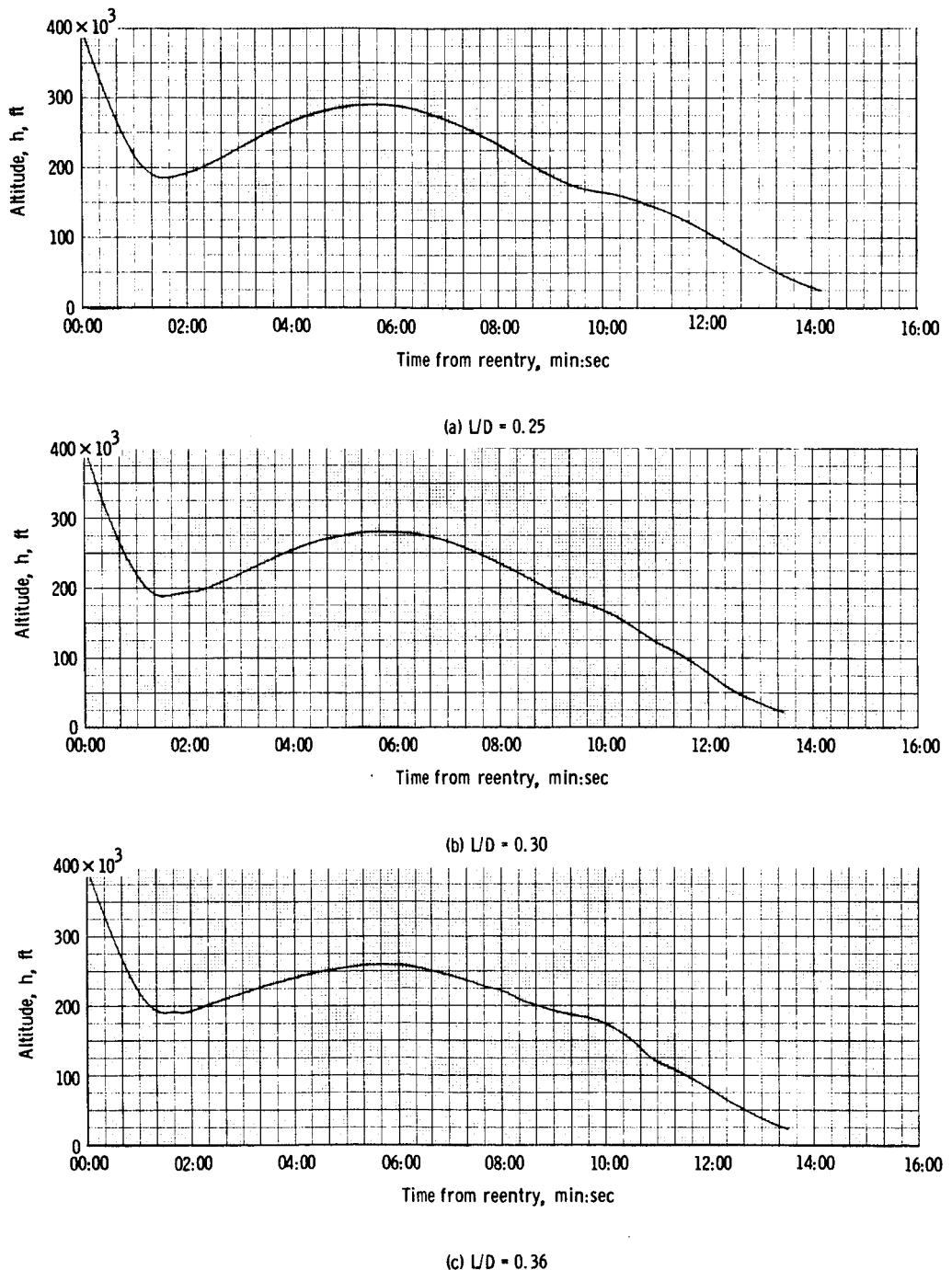


Figure 24. - Altitude versus time from reentry with reentry range of 2500 nautical miles and a flight-path angle of -6.30 degrees.

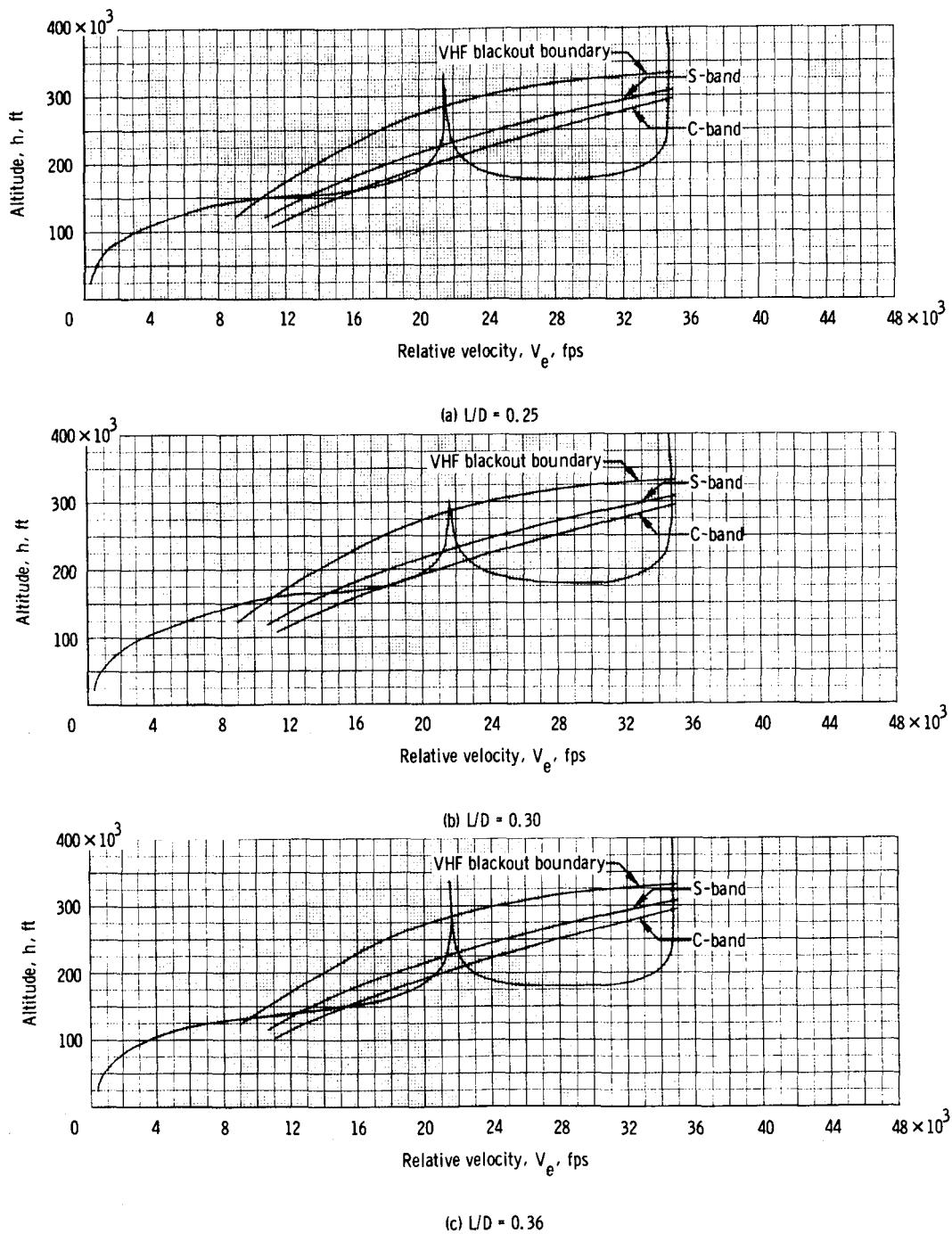


Figure 25. - Communications blackout region for lunar returns with a range to target at reentry of 2500 nautical miles and a flight-path angle of -6.70 degrees.

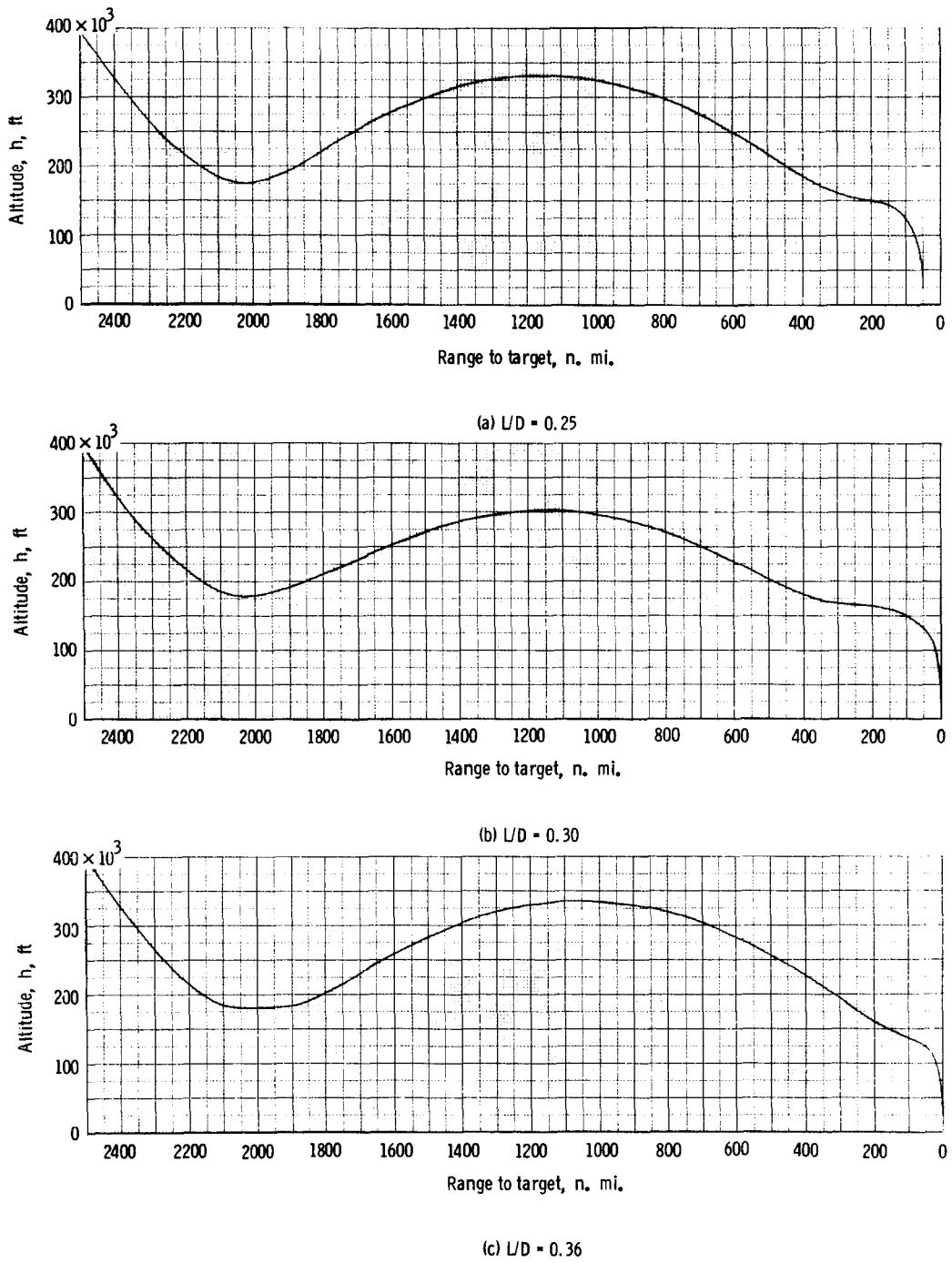


Figure 26. - Altitude versus range to target for a lunar return with a range to target at reentry of 2500 nautical miles and a flight-path angle of -6.70 degrees.

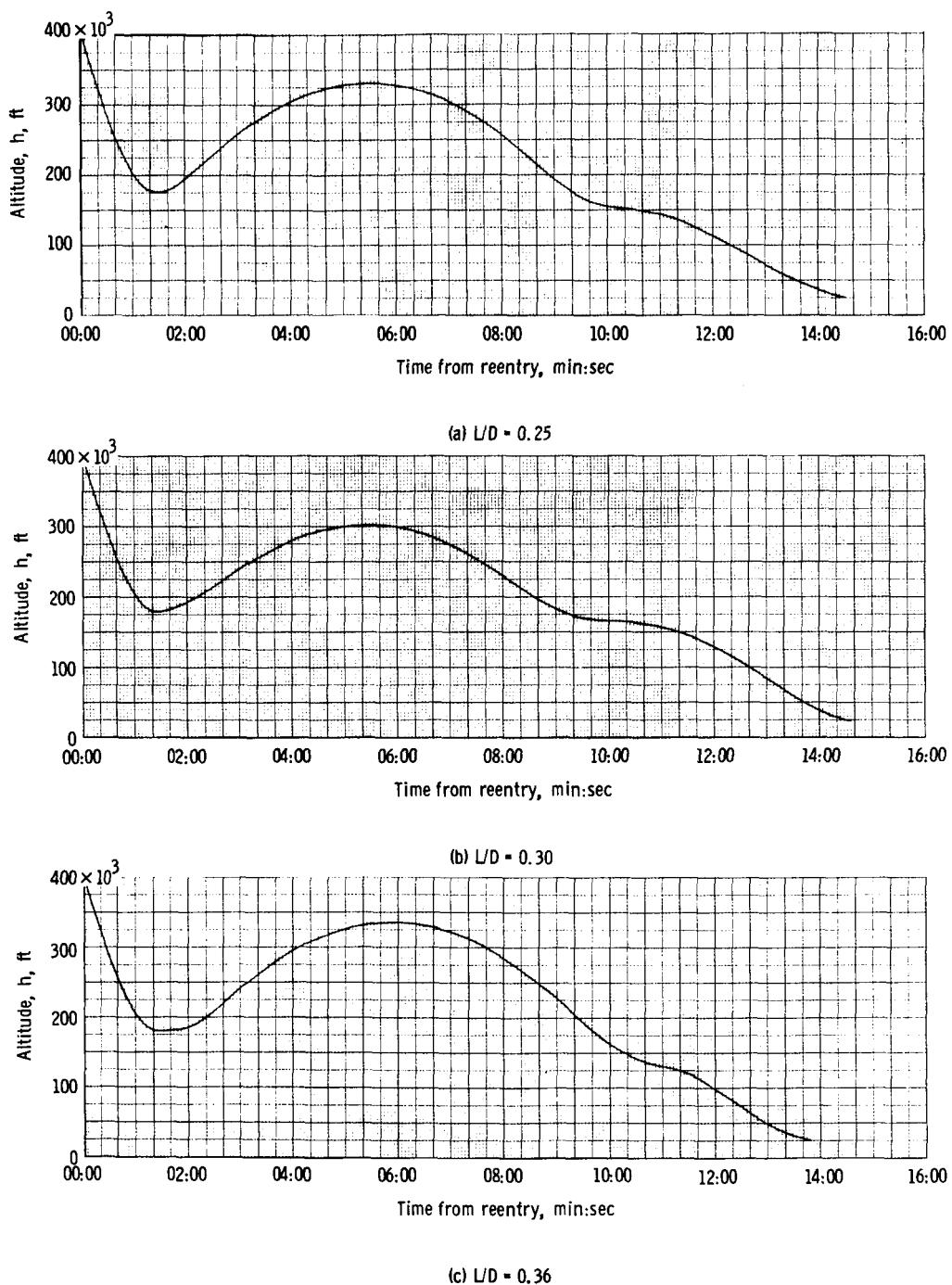


Figure 27. - Altitude versus time from reentry with reentry range of 2500 nautical miles and a flight-path angle of  $-6.70$  degrees.

## REFERENCES

1. Burton, John: Communications Blackout Regions for Lunar Returns Using the AS-504 Reentry Guidance Logic. MSC Internal Note 66-FM-142, November 25, 1966.
2. Morth, Raymond: Apollo Guidance and Navigation. MIT Document R-532, January, 1966.
3. Lehnert, Richard; and Rosenbaum, Bernard: Plasma Effect on Apollo Reentry Communication. TN-2732, January, 1964.